US009069871B2

(12) **United States Patent**
Itoko et al.

(10) **Patent No.: US 9,069,871 B2**
(45) **Date of Patent: Jun. 30, 2015**

(54) **SYSTEM, METHOD, AND PROGRAM FOR GENERATING WEB PAGE**

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(73) Assignee: **INTERNATIONAL BUSINESS MACHINES CORPORATION**, Armonk, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 137 days.

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US 2012/0079361 A1 Mar. 29, 2012

(30) **Foreign Application Priority Data**

Sep. 27, 2010 (JP) 2010-214942

(51) **Int. Cl.**
G06F 17/22 (2006.01)
G06F 17/30 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 17/3089*** (2013.01); ***G06F 17/30887*** (2013.01)

(58) **Field of Classification Search**
USPC 715/234, 239, 241, 242, 243, 248
See application file for complete search history.

(56) **References Cited**

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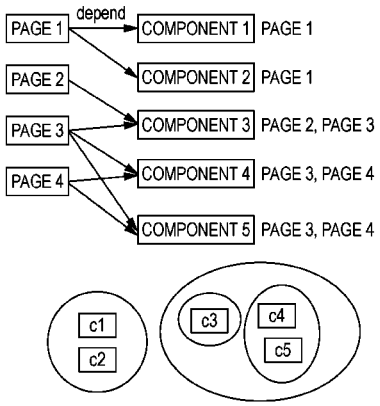
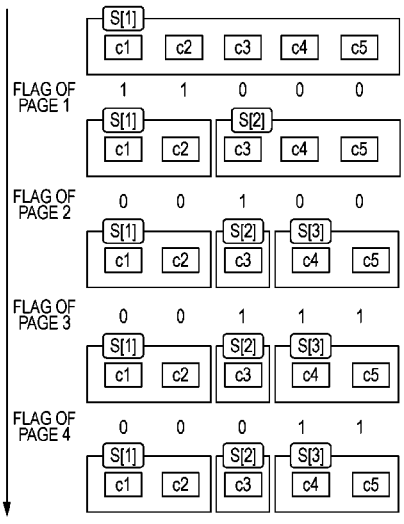
Assistant Examiner — Wilson Tsui
(74) *Attorney, Agent, or Firm* — Tutunjian & Bitetto, P.C.; Jennifer R. Davis

(57) **ABSTRACT**

A method, article, and system for reconfiguring a web page. The method includes extracting dependencies between pages, files, and components of the web page, measuring a network delay value, a transfer efficiency value, and a component size, estimating load time of a candidate file using information of the network delay value, the transfer efficiency value, the dependencies, and the component size. An integer programming problem is generated to minimize an object function representing the load time of the web page by analyzing the web page, solving the integer programming problem, reconfiguring a library file from the solution and reconfiguring the web page by replacing a link to the library file of each page with a link to the reorganized file.

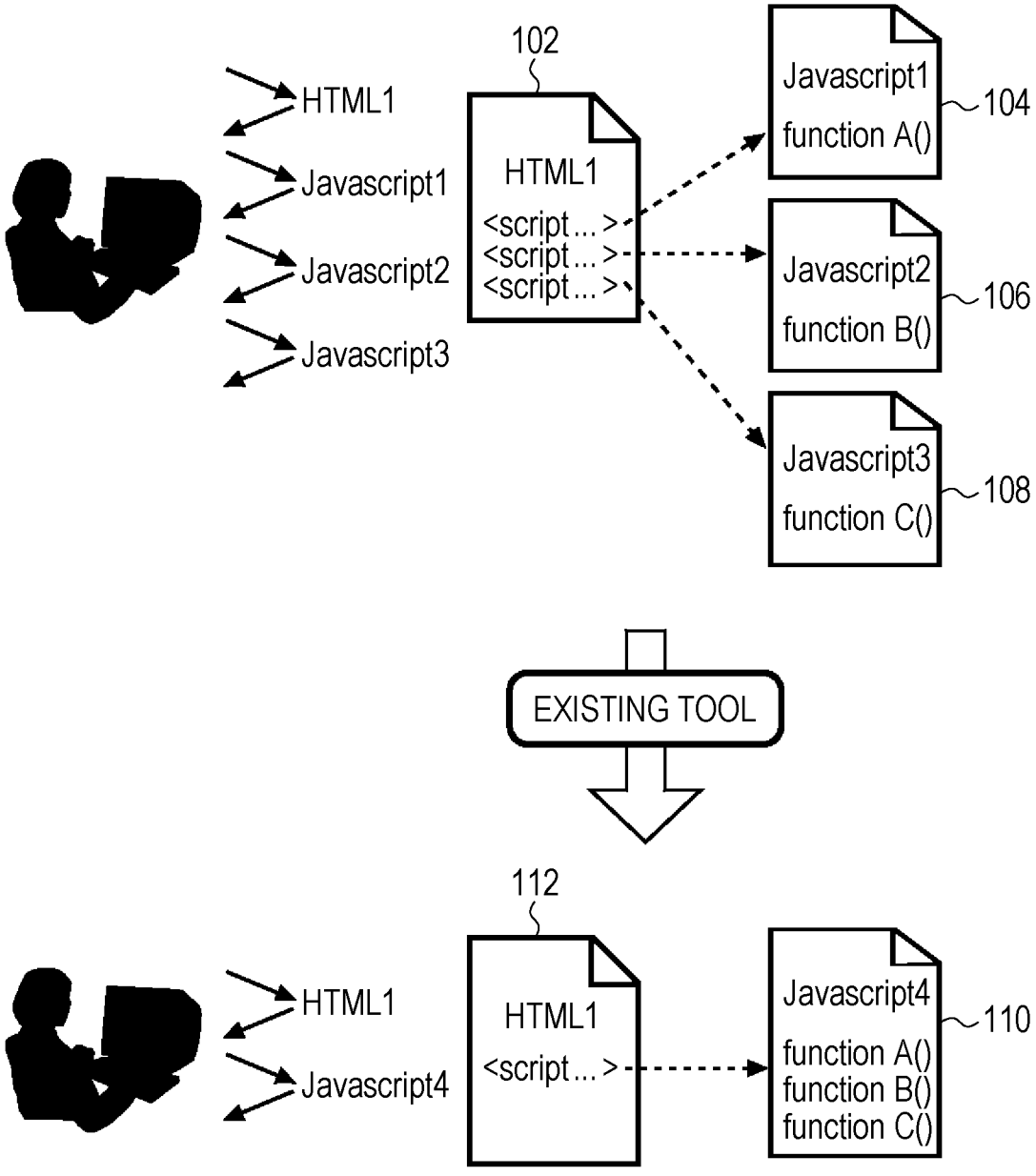
18 Claims, 35 Drawing Sheets





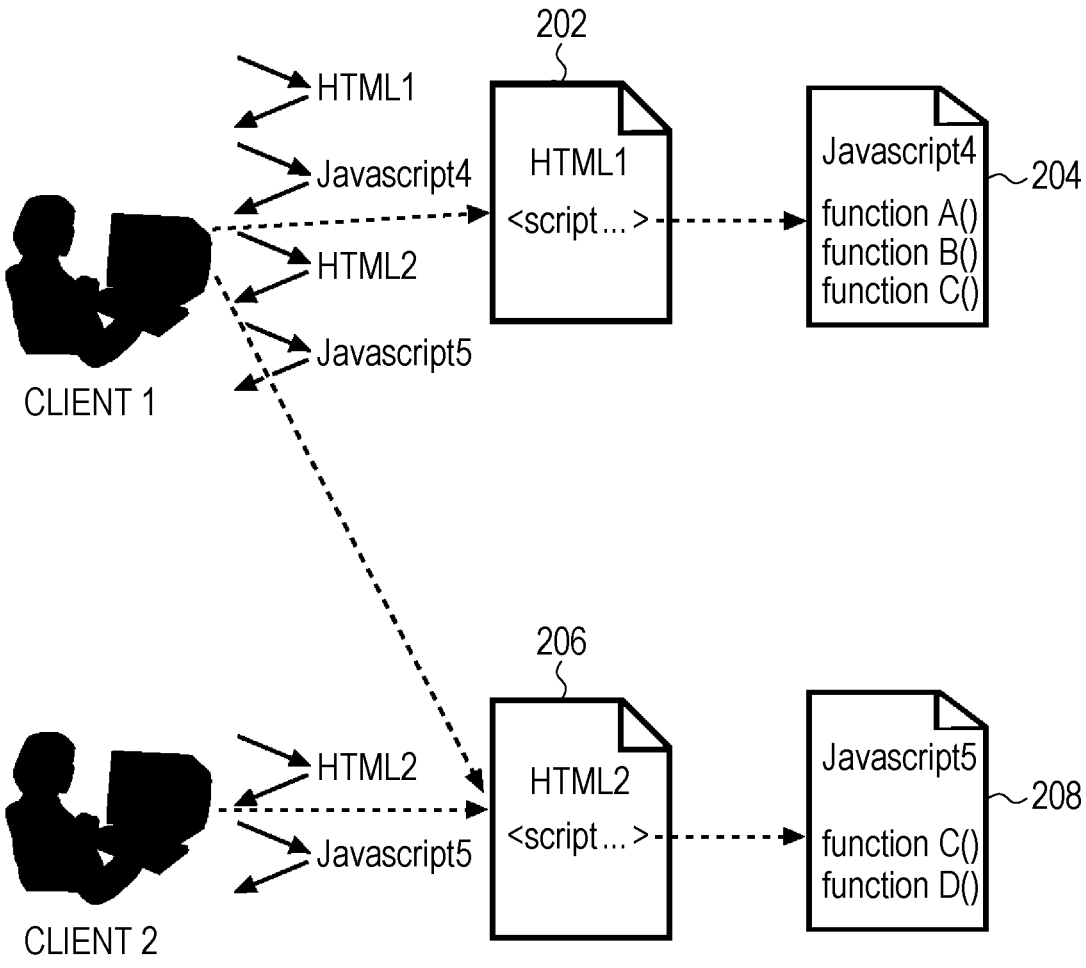
PRIOR ART

FIG. 1



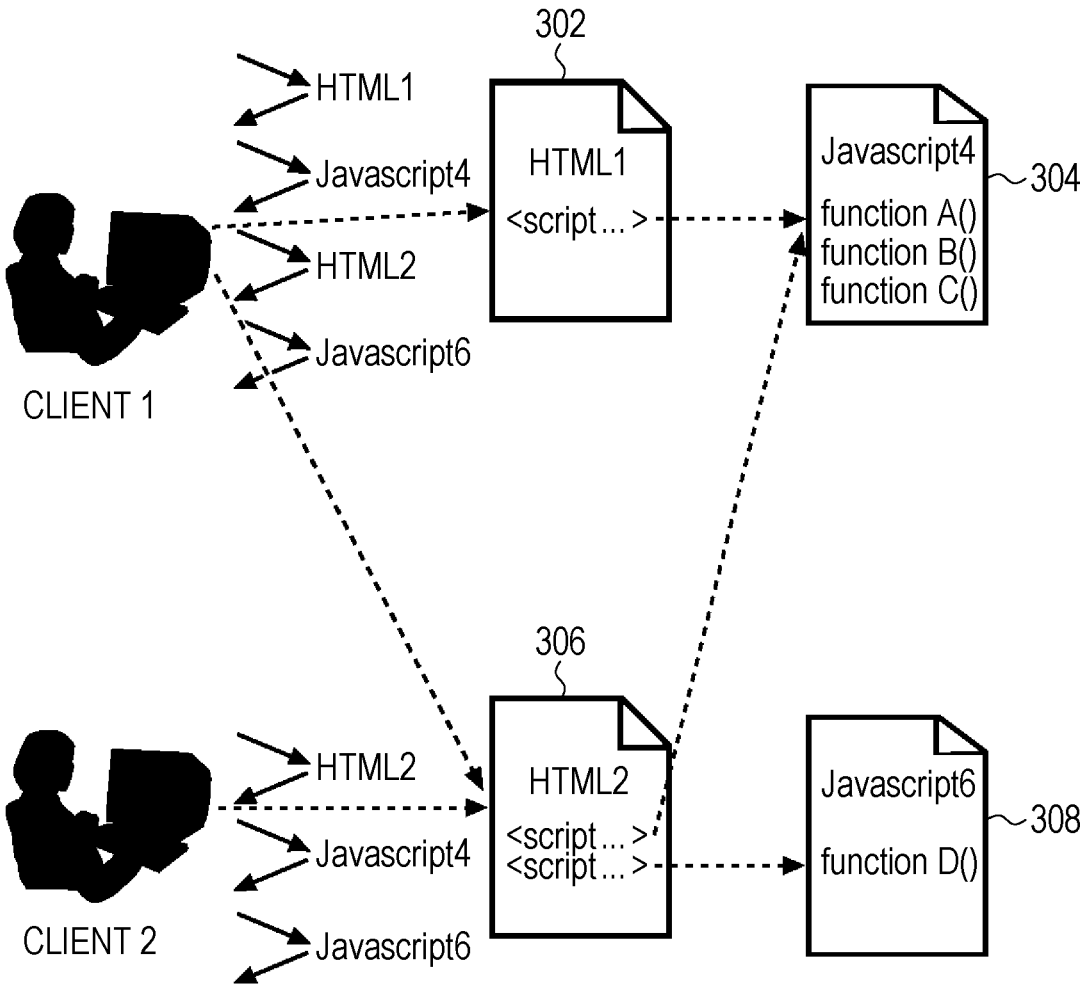
PRIOR ART

FIG. 2



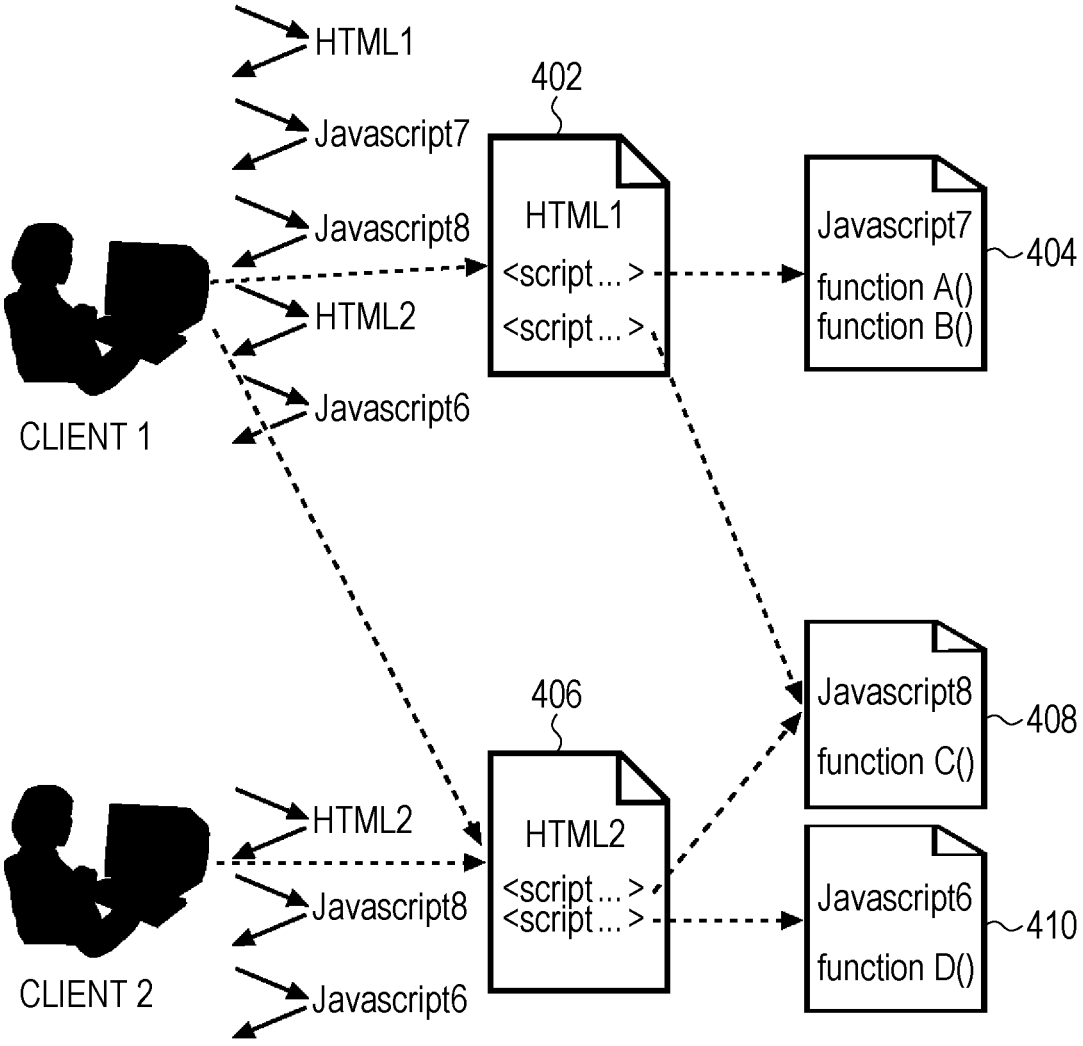
PRIOR ART

FIG. 3



PRIOR ART

FIG. 4



PRIOR ART

FIG. 5

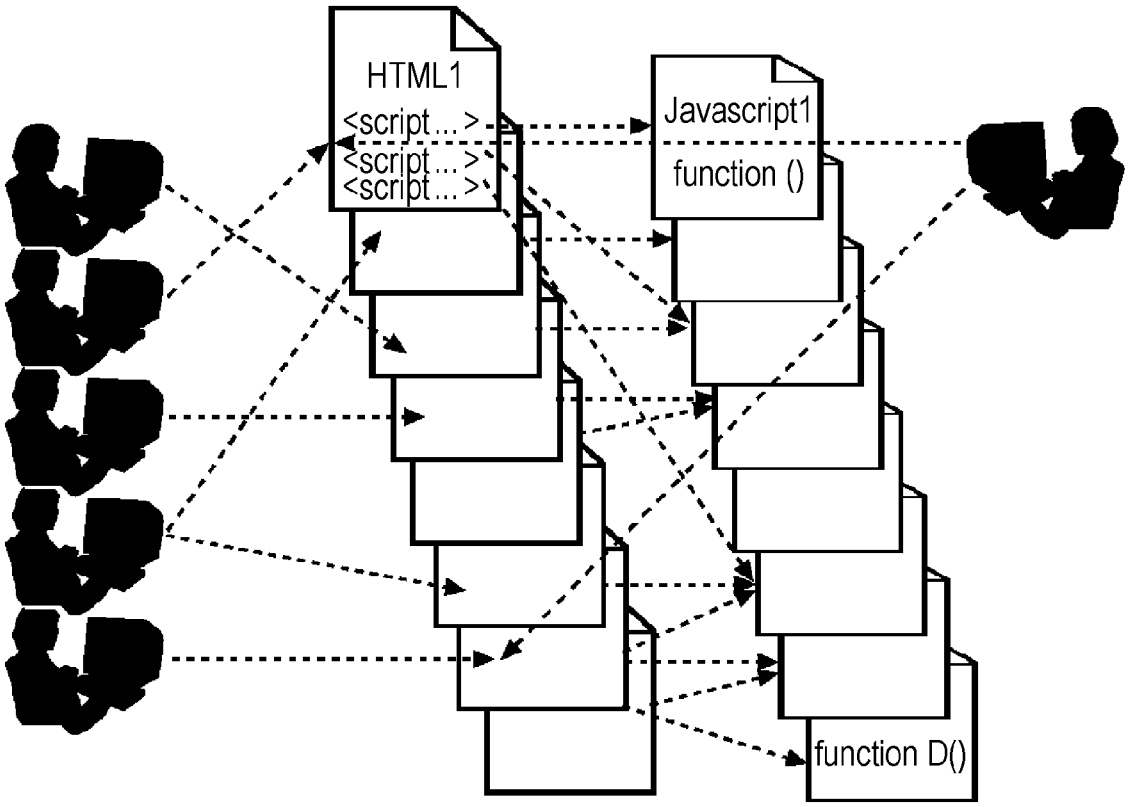


FIG. 6

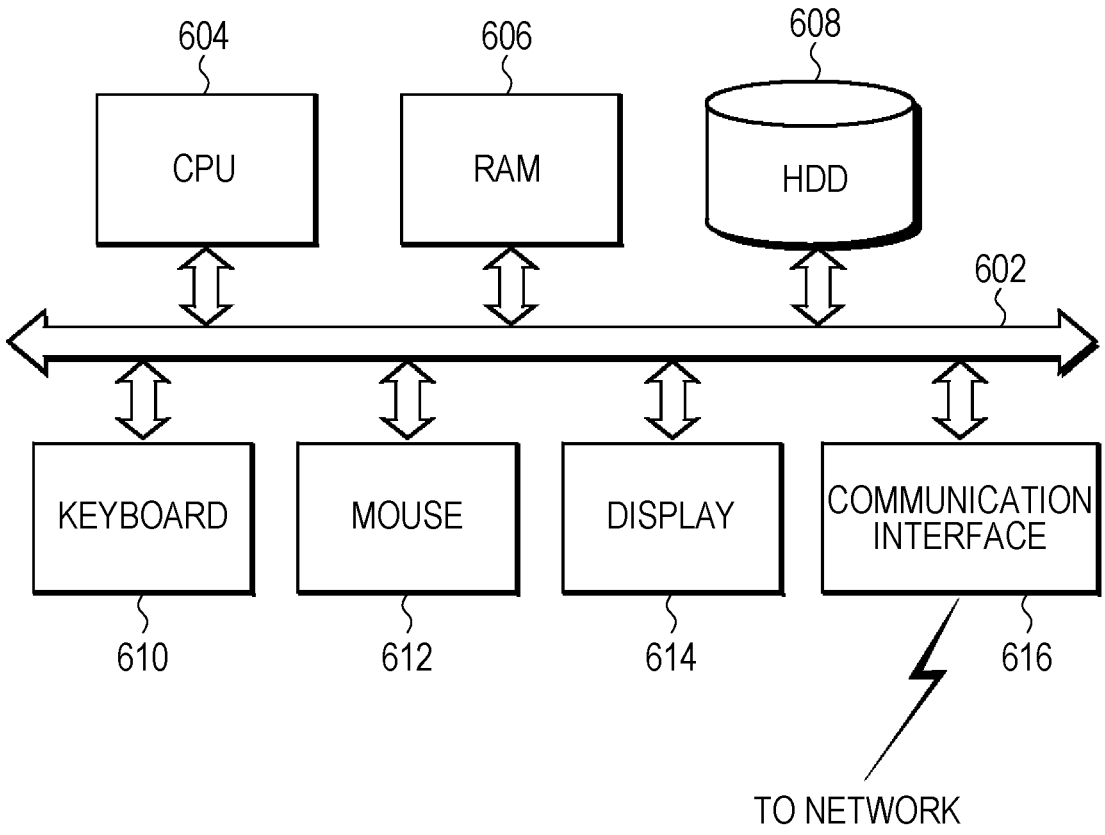

604
606
608
CPU
RAM
HDD
602
KEYBOARD
MOUSE
DISPLAY
COMMUNICATION INTERFACE
610
612
614
616
TO NETWORK

FIG. 7

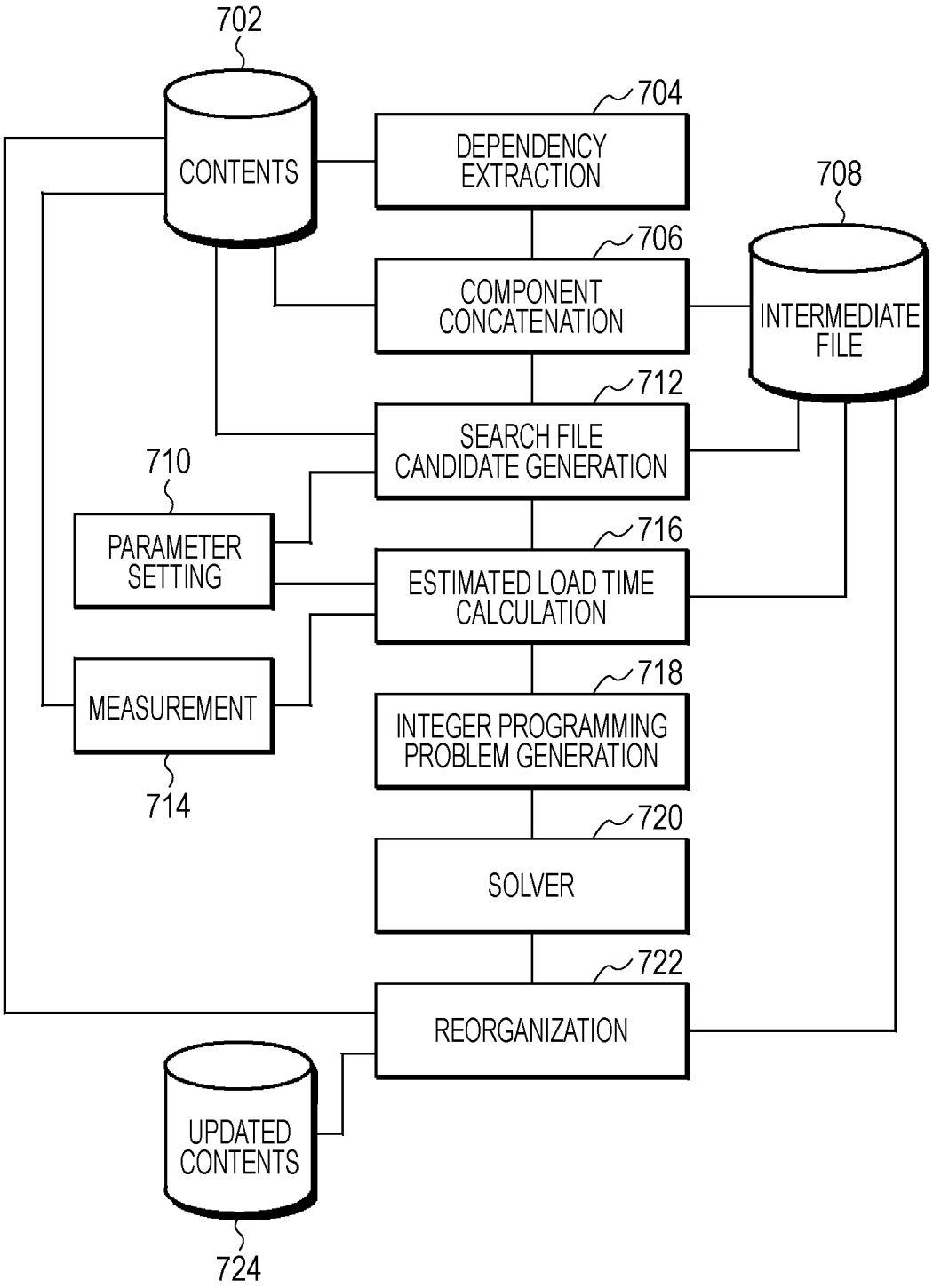

702
CONTENTS
704
DEPENDENCY EXTRACTION
708
INTERMEDIATE FILE
706
COMPONENT CONCATENATION
712
SEARCH FILE CANDIDATE GENERATION
710
PARAMETER SETTING
716
ESTIMATED LOAD TIME CALCULATION
MEASUREMENT
718
INTEGER PROGRAMMING PROBLEM GENERATION
714
720
SOLVER
722
REORGANIZATION
UPDATED CONTENTS
724

FIG. 8(a)

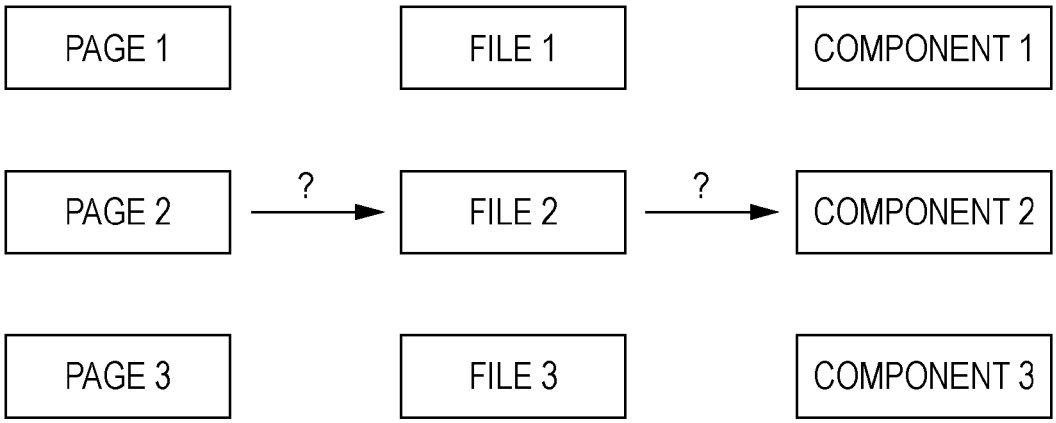

PAGE 1
FILE 1
COMPONENT 1
PAGE 2
?
FILE 2
?
COMPONENT 2
PAGE 3
FILE 3
COMPONENT 3

FIG. 8(b)

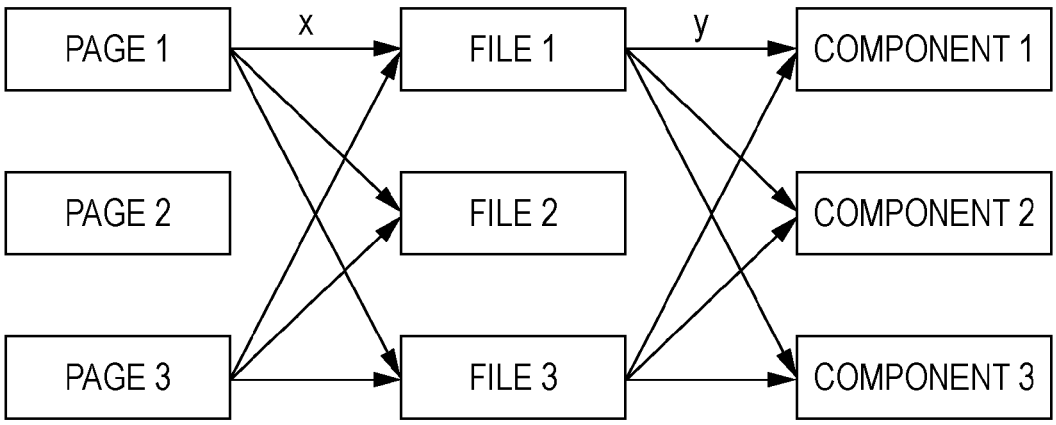

PAGE 1
x
FILE 1
y
COMPONENT 1
PAGE 2
FILE 2
COMPONENT 2
PAGE 3
FILE 3
COMPONENT 3

FIG. 9(a)

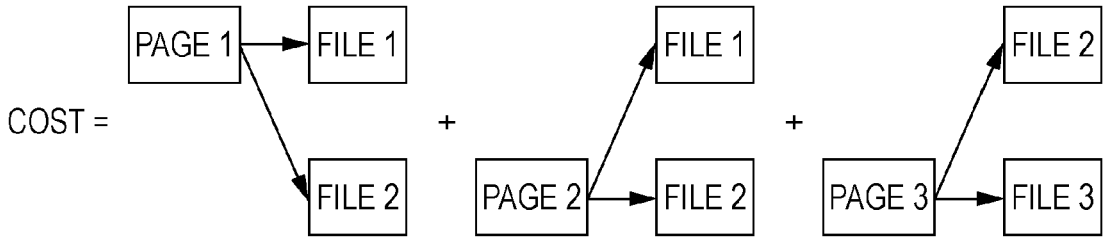


FIG. 9(b)

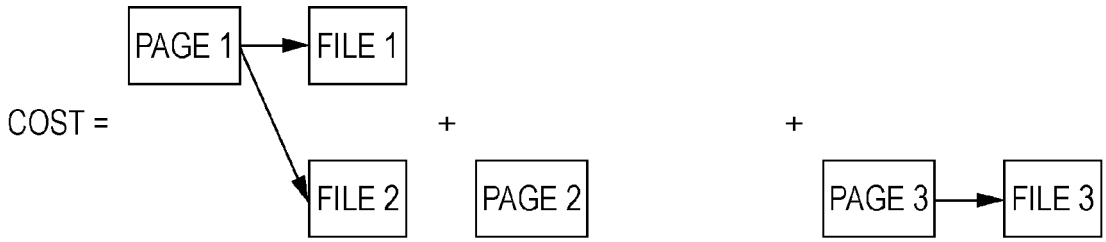


FIG. 10

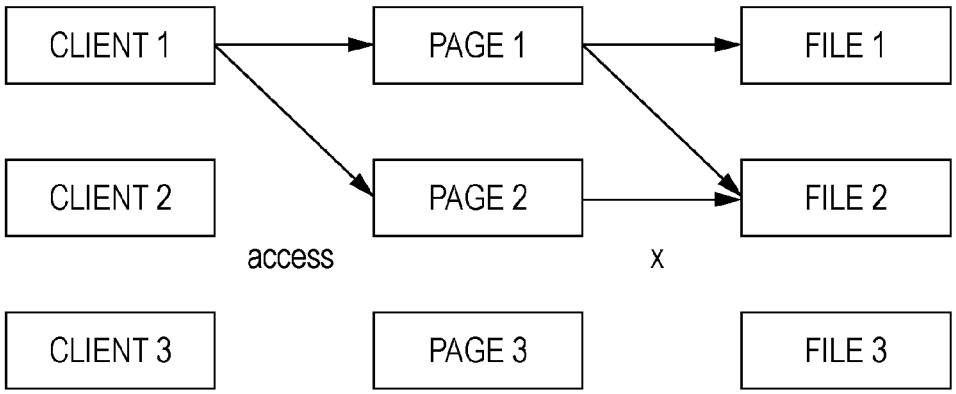


FIG. 11(a)

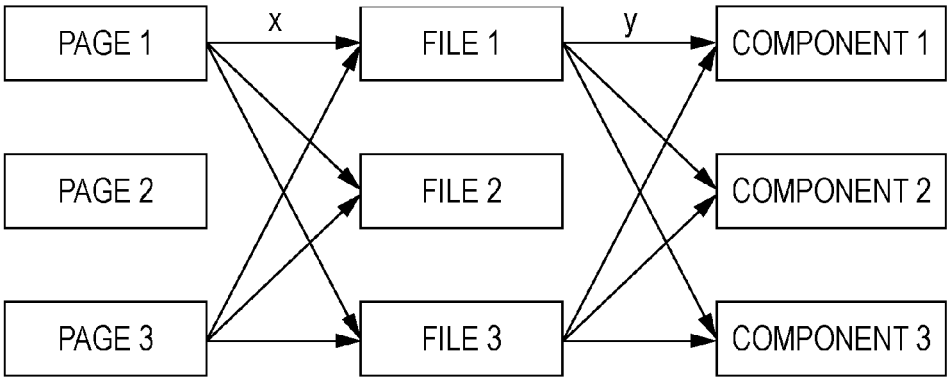


FIG. 11(b)

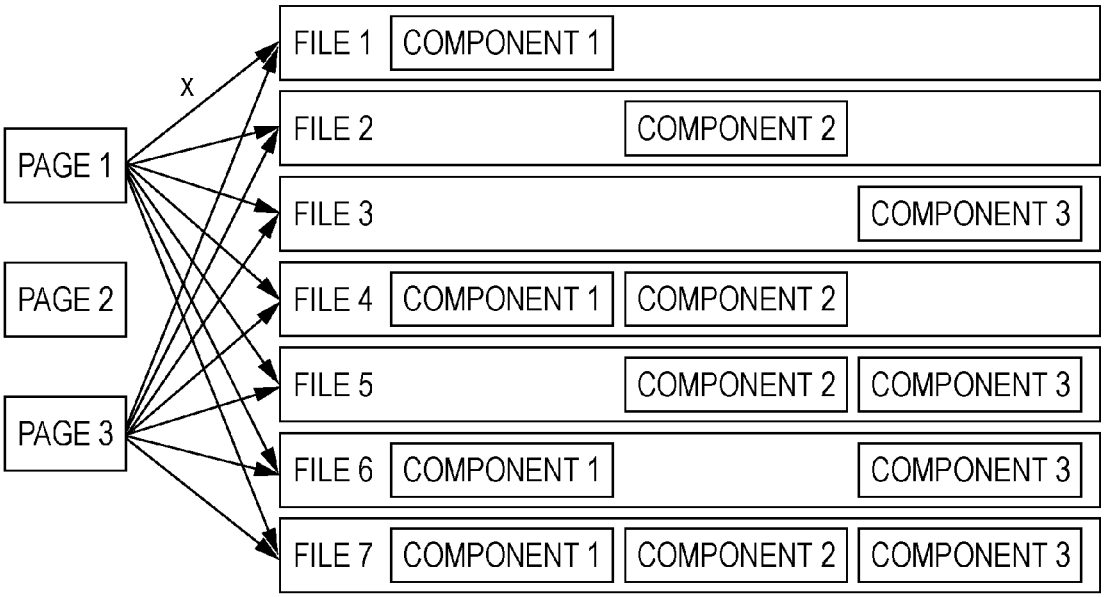


FIG. 12(a)

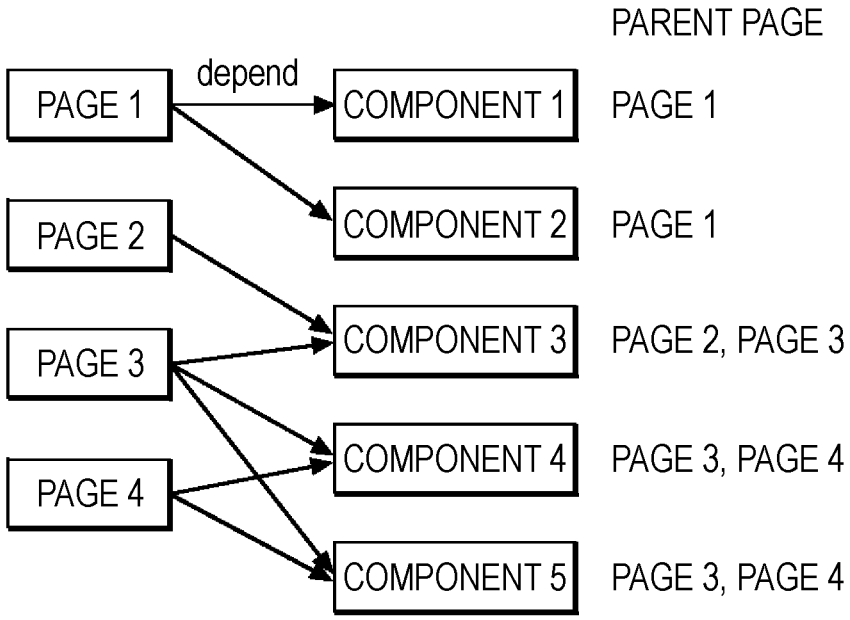


FIG. 12(b)

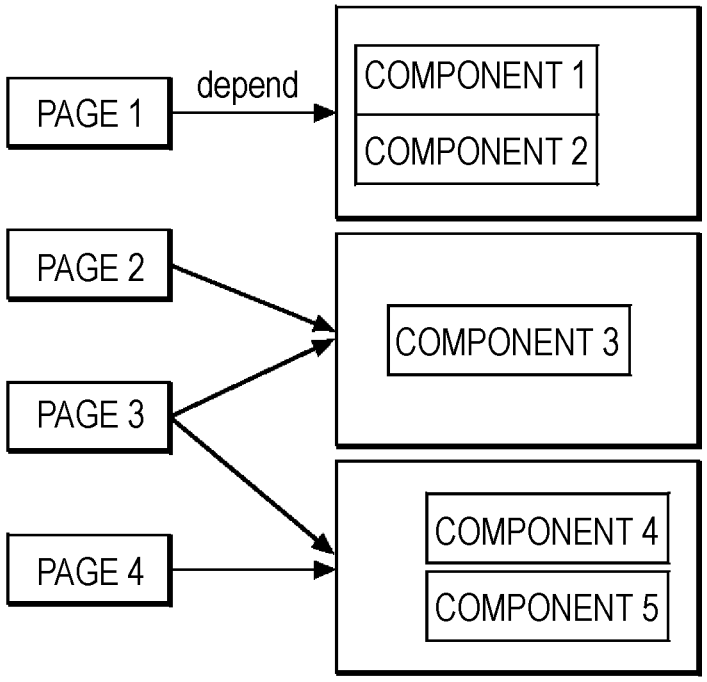


FIG. 13

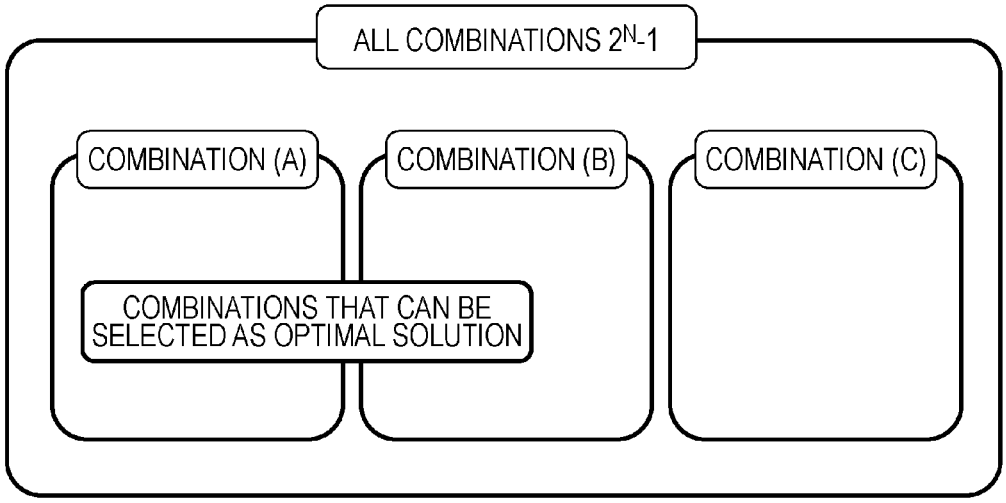

ALL COMBINATIONS 2^N-1
COMBINATION (A)
COMBINATION (B)
COMBINATION (C)
COMBINATIONS THAT CAN BE SELECTED AS OPTIMAL SOLUTION

FIG. 14

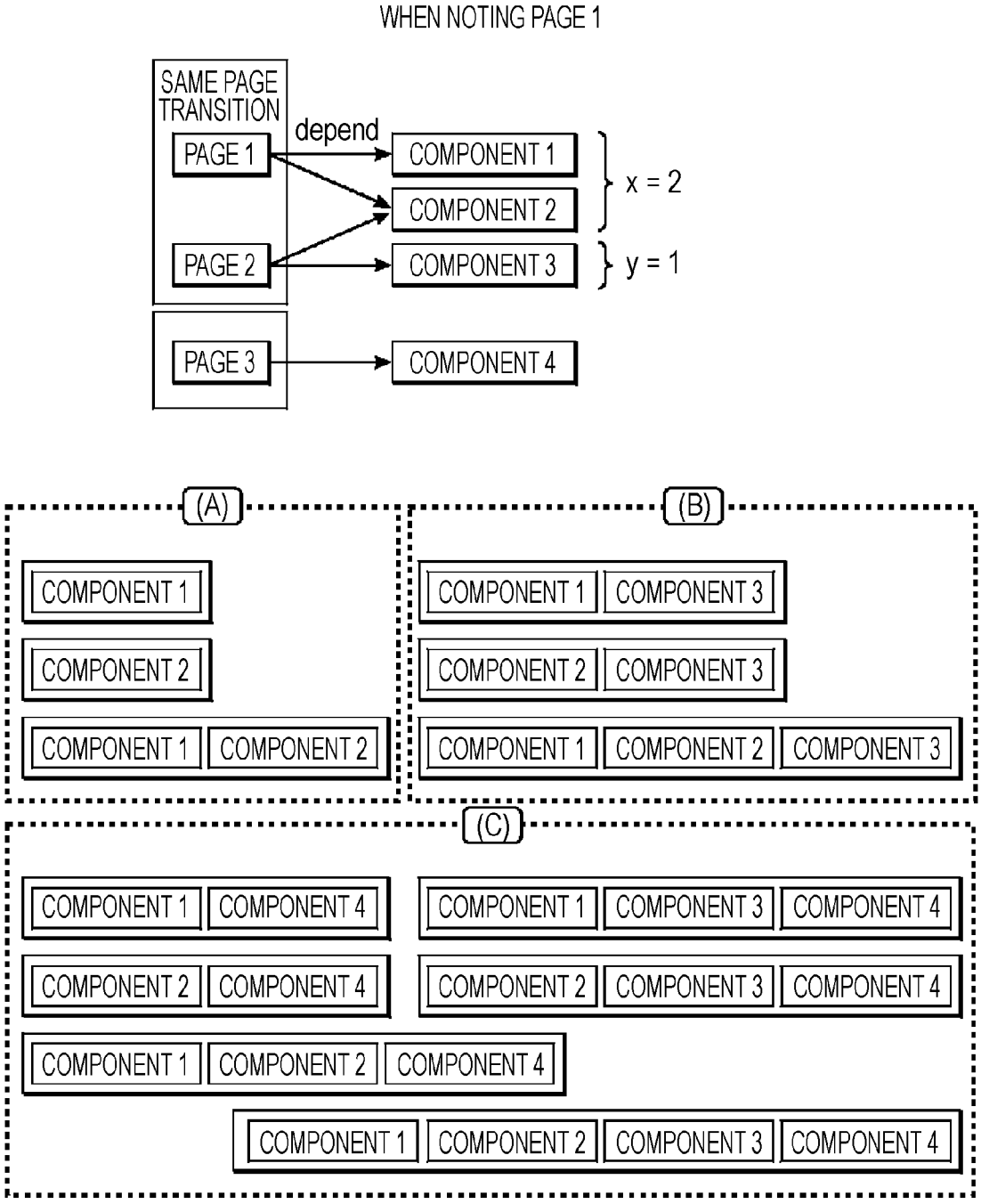

WHEN NOTING PAGE 1
SAME PAGE TRANSITION
depend
PAGE 1
PAGE 2
PAGE 3
COMPONENT 1
COMPONENT 2
COMPONENT 3
COMPONENT 4
x = 2
y = 1
(A)
COMPONENT 1
COMPONENT 2
COMPONENT 1 COMPONENT 2
(B)
COMPONENT 1 COMPONENT 3
COMPONENT 2 COMPONENT 3
COMPONENT 1 COMPONENT 2 COMPONENT 3
(C)
COMPONENT 1 COMPONENT 4
COMPONENT 2 COMPONENT 4
COMPONENT 1 COMPONENT 2 COMPONENT 4
COMPONENT 1 COMPONENT 3 COMPONENT 4
COMPONENT 2 COMPONENT 3 COMPONENT 4
COMPONENT 1 COMPONENT 2 COMPONENT 3 COMPONENT 4

FIG. 15

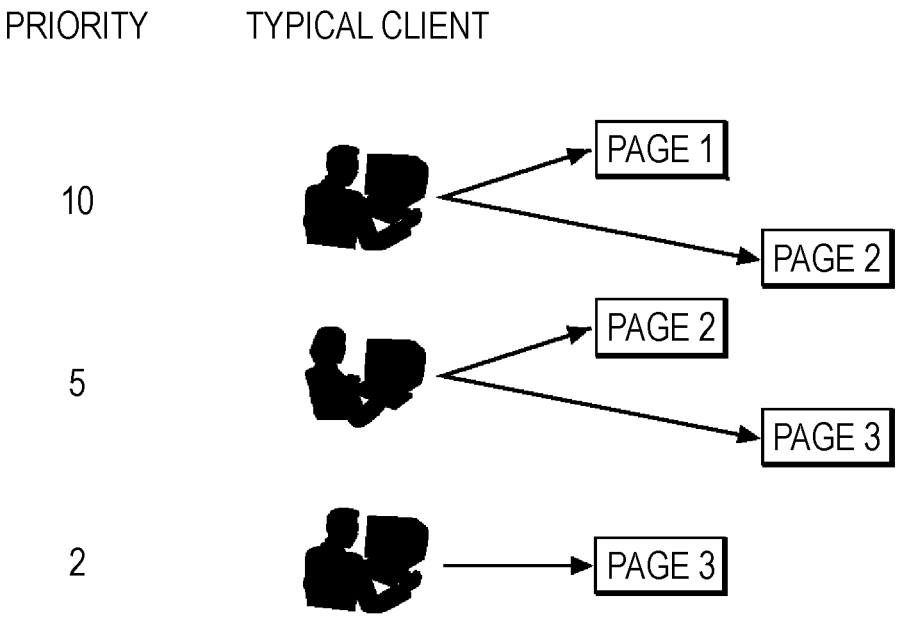

PRIORITY
TYPICAL CLIENT
10
PAGE 1
PAGE 2
5
PAGE 2
PAGE 3
2
PAGE 3

FIG. 16

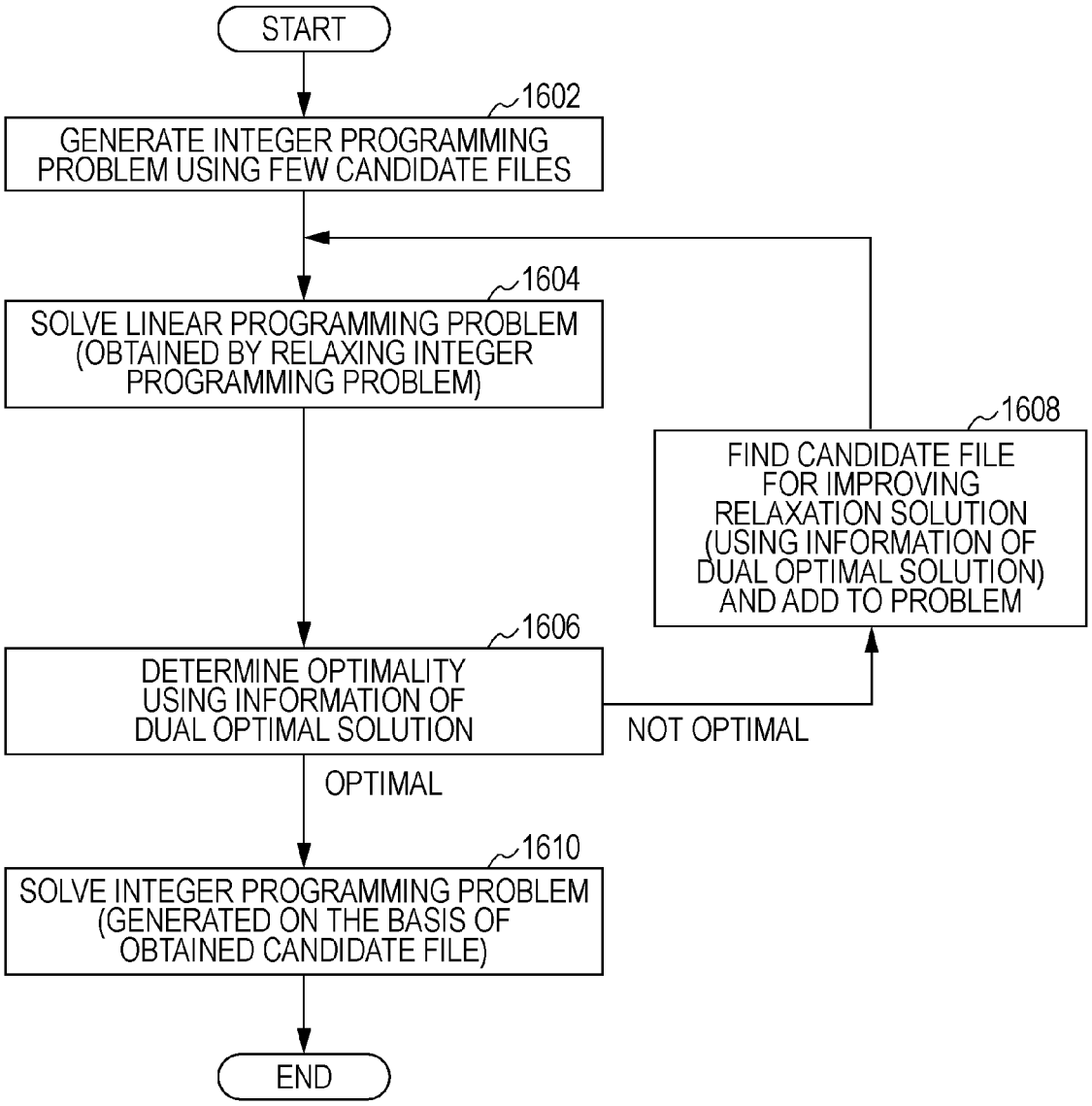

START
1602
GENERATE INTEGER PROGRAMMING PROBLEM USING FEW CANDIDATE FILES
1604
SOLVE LINEAR PROGRAMMING PROBLEM (OBTAINED BY RELAXING INTEGER PROGRAMMING PROBLEM)
1608
FIND CANDIDATE FILE FOR IMPROVING RELAXATION SOLUTION (USING INFORMATION OF DUAL OPTIMAL SOLUTION) AND ADD TO PROBLEM
1606
DETERMINE OPTIMALITY USING INFORMATION OF DUAL OPTIMAL SOLUTION
NOT OPTIMAL
OPTIMAL
1610
SOLVE INTEGER PROGRAMMING PROBLEM (GENERATED ON THE BASIS OF OBTAINED CANDIDATE FILE)
END

FIG. 17

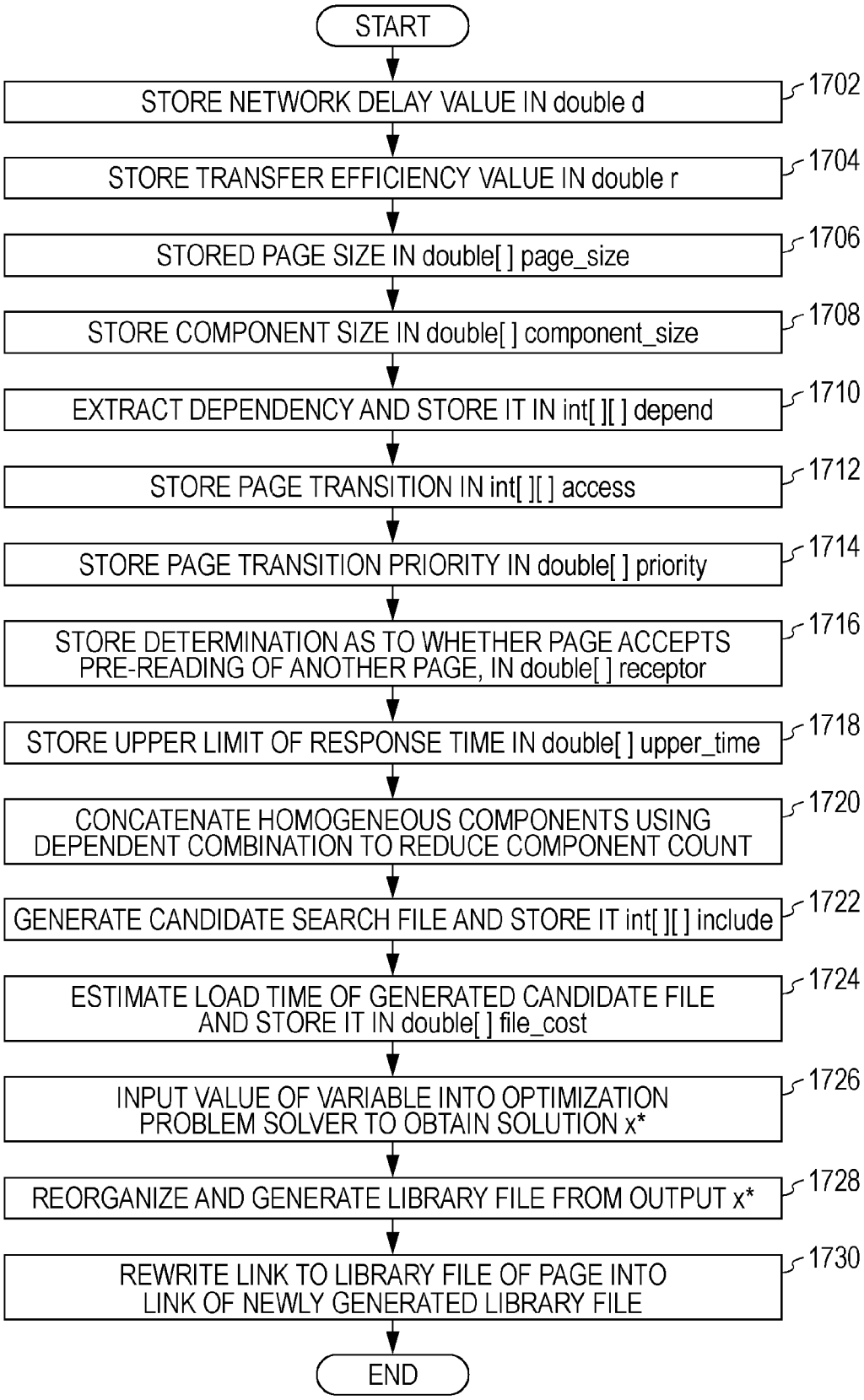

START
STORE NETWORK DELAY VALUE IN double d
1702
STORE TRANSFER EFFICIENCY VALUE IN double r
1704
STORED PAGE SIZE IN double[ ] page_size
1706
STORE COMPONENT SIZE IN double[ ] component_size
1708
EXTRACT DEPENDENCY AND STORE IT IN int[ ][ ] depend
1710
STORE PAGE TRANSITION IN int[ ][ ] access
1712
STORE PAGE TRANSITION PRIORITY IN double[ ] priority
1714
STORE DETERMINATION AS TO WHETHER PAGE ACCEPTS PRE-READING OF ANOTHER PAGE, IN double[ ] receptor
1716
STORE UPPER LIMIT OF RESPONSE TIME IN double[ ] upper_time
1718
CONCATENATE HOMOGENEOUS COMPONENTS USING DEPENDENT COMBINATION TO REDUCE COMPONENT COUNT
1720
GENERATE CANDIDATE SEARCH FILE AND STORE IT int[ ][ ] include
1722
ESTIMATE LOAD TIME OF GENERATED CANDIDATE FILE AND STORE IT IN double[ ] file_cost
1724
INPUT VALUE OF VARIABLE INTO OPTIMIZATION PROBLEM SOLVER TO OBTAIN SOLUTION x*
1726
REORGANIZE AND GENERATE LIBRARY FILE FROM OUTPUT x*
1728
REWRITE LINK TO LIBRARY FILE OF PAGE INTO LINK OF NEWLY GENERATED LIBRARY FILE
1730
END

FIG. 18

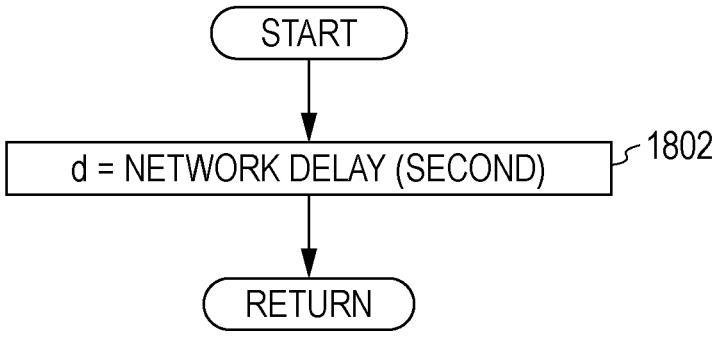

START
d = NETWORK DELAY (SECOND)
1802
RETURN

FIG. 19

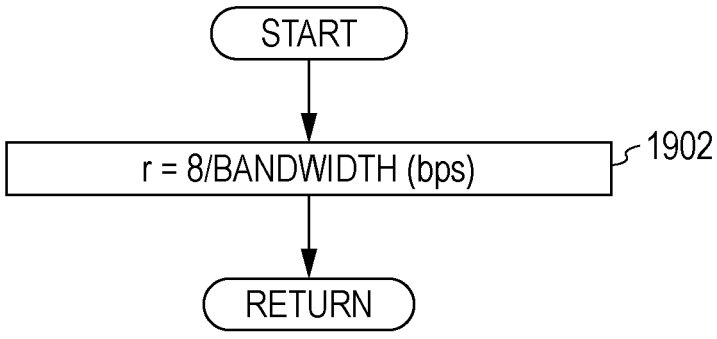

START
r = 8/BANDWIDTH (bps)
1902
RETURN

FIG. 20

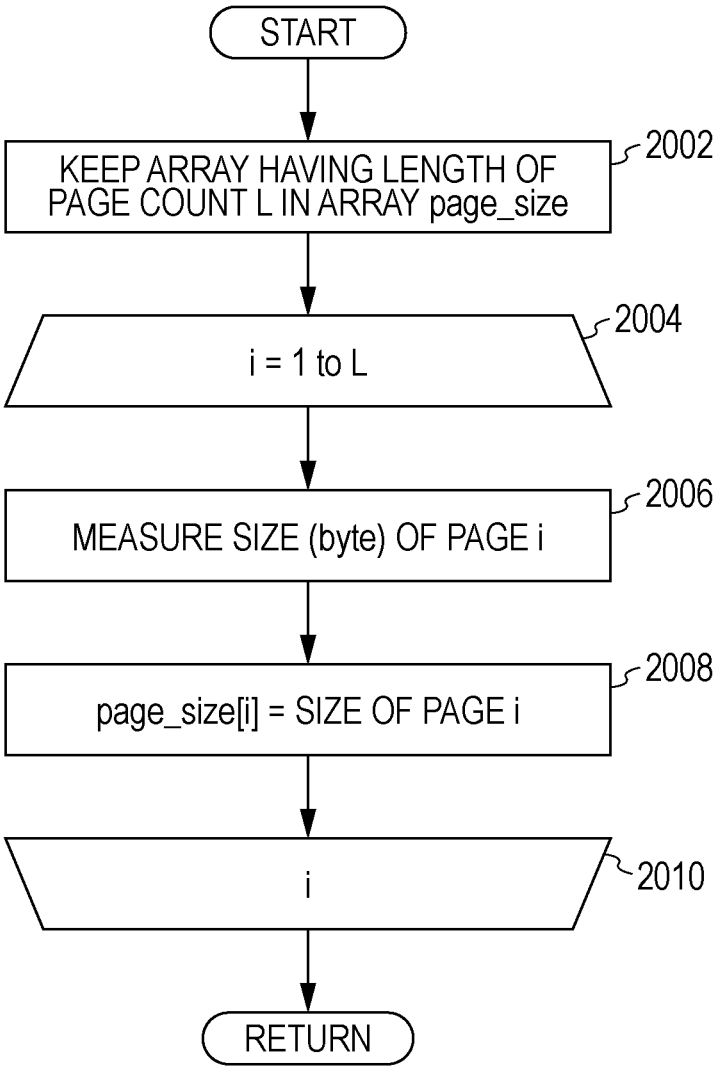

START
KEEP ARRAY HAVING LENGTH OF PAGE COUNT L IN ARRAY page_size
2002
i = 1 to L
2004
MEASURE SIZE (byte) OF PAGE i
2006
page_size[i] = SIZE OF PAGE i
2008
i
2010
RETURN

FIG. 21

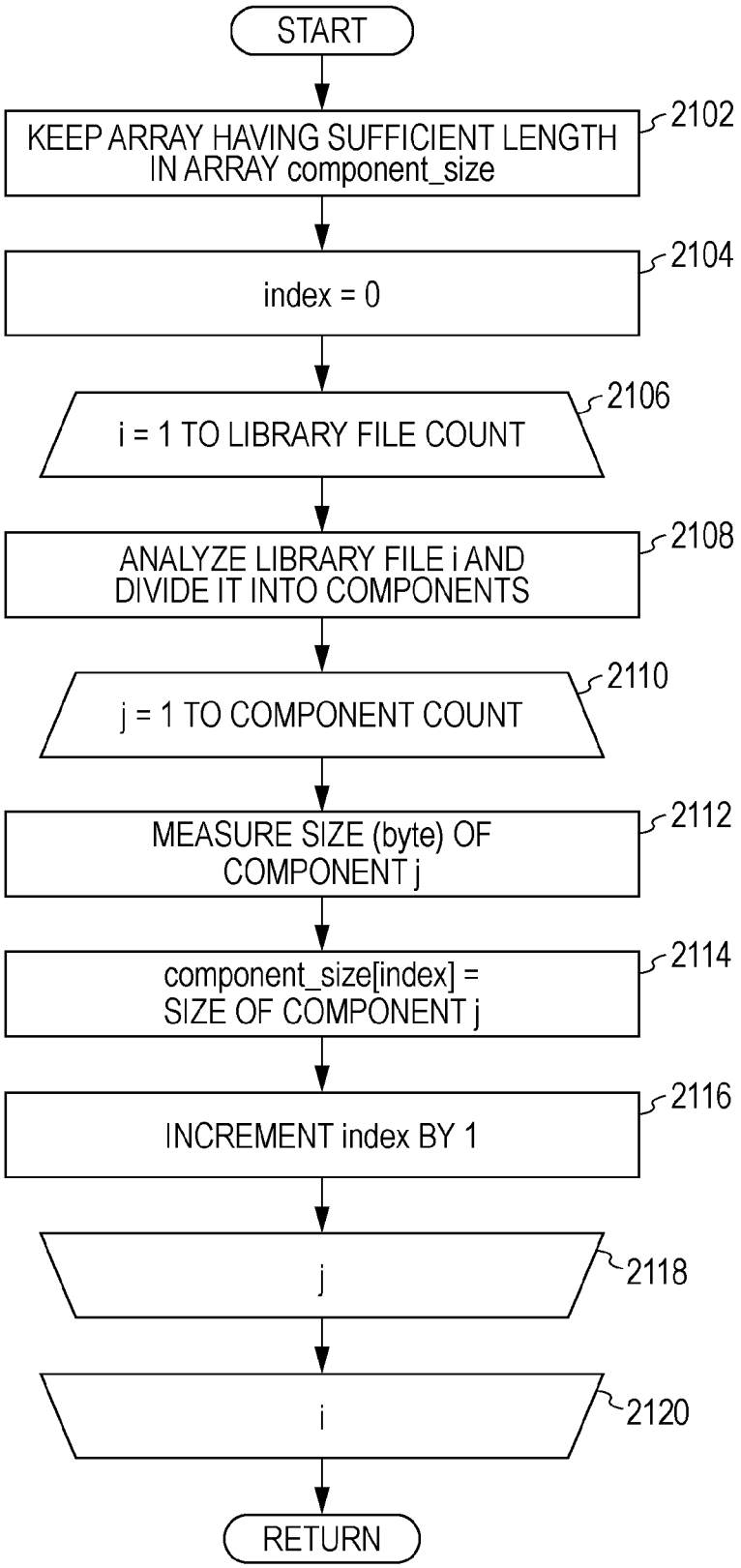

START
KEEP ARRAY HAVING SUFFICIENT LENGTH IN ARRAY component_size
2102
index = 0
2104
i = 1 TO LIBRARY FILE COUNT
2106
ANALYZE LIBRARY FILE i AND DIVIDE IT INTO COMPONENTS
2108
j = 1 TO COMPONENT COUNT
2110
MEASURE SIZE (byte) OF COMPONENT j
2112
component_size[index] = SIZE OF COMPONENT j
2114
INCREMENT index BY 1
2116
j
2118
i
2120
RETURN

FIG. 22

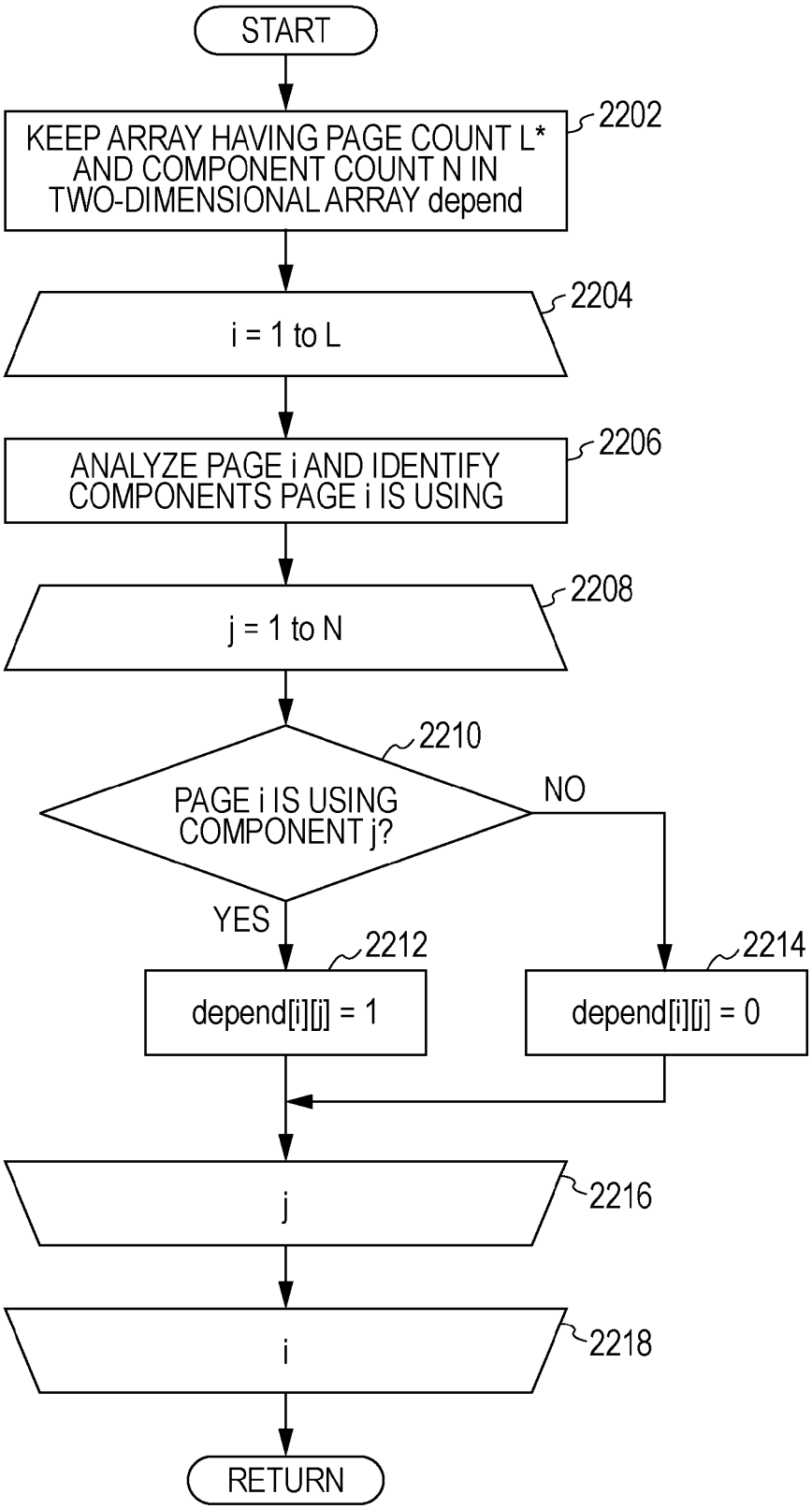

START
KEEP ARRAY HAVING PAGE COUNT L* AND COMPONENT COUNT N IN TWO-DIMENSIONAL ARRAY depend
2202
i = 1 to L
2204
ANALYZE PAGE i AND IDENTIFY COMPONENTS PAGE i IS USING
2206
j = 1 to N
2208
PAGE i IS USING COMPONENT j?
2210
NO
YES
depend[i][j] = 1
2212
depend[i][j] = 0
2214
j
2216
i
2218
RETURN

FIG. 23

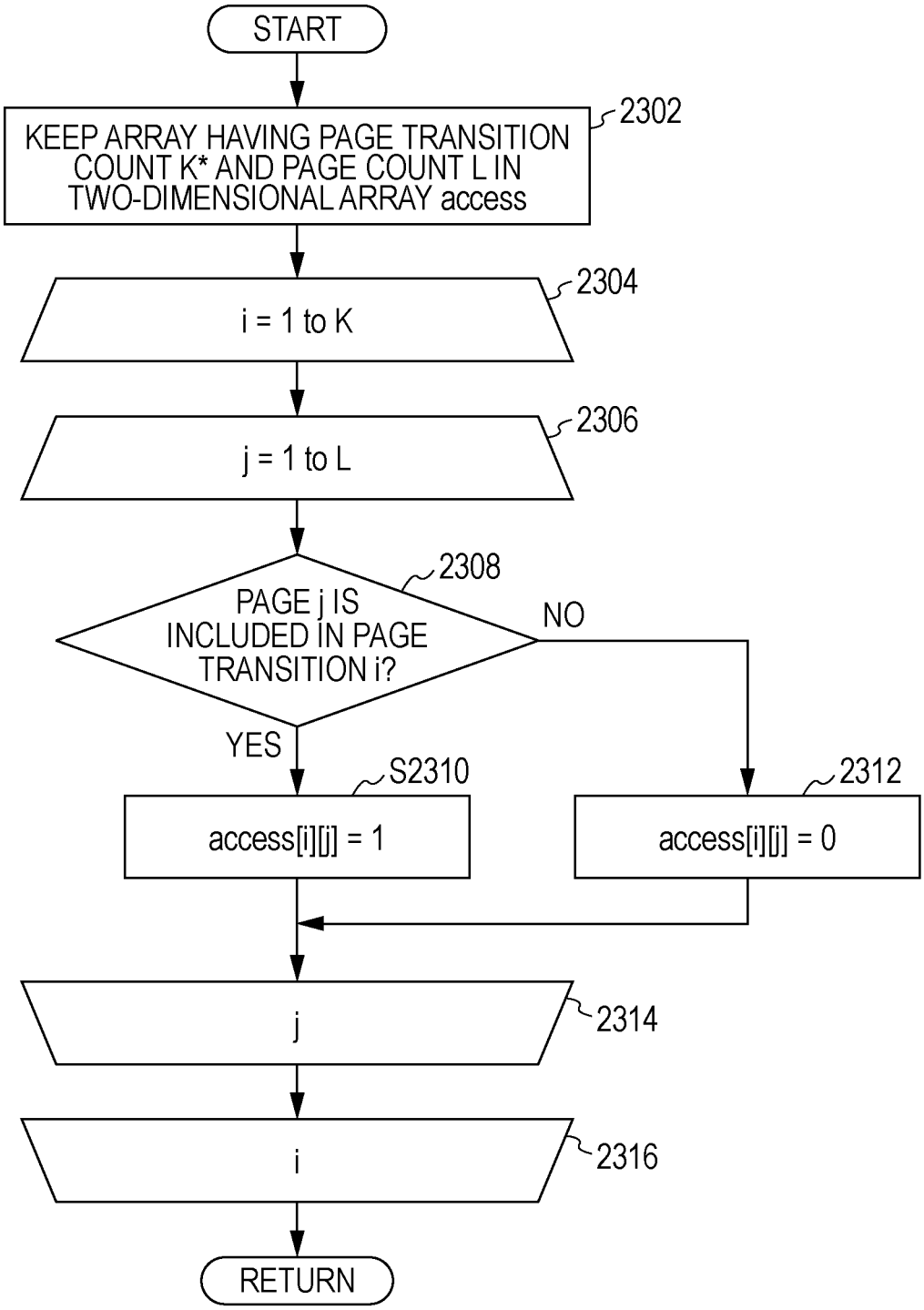

START
KEEP ARRAY HAVING PAGE TRANSITION COUNT K* AND PAGE COUNT L IN TWO-DIMENSIONAL ARRAY access
2302
i = 1 to K
2304
j = 1 to L
2306
PAGE j IS INCLUDED IN PAGE TRANSITION i?
2308
NO
YES
S2310
access[i][j] = 1
2312
access[i][j] = 0
j
2314
i
2316
RETURN

FIG. 24

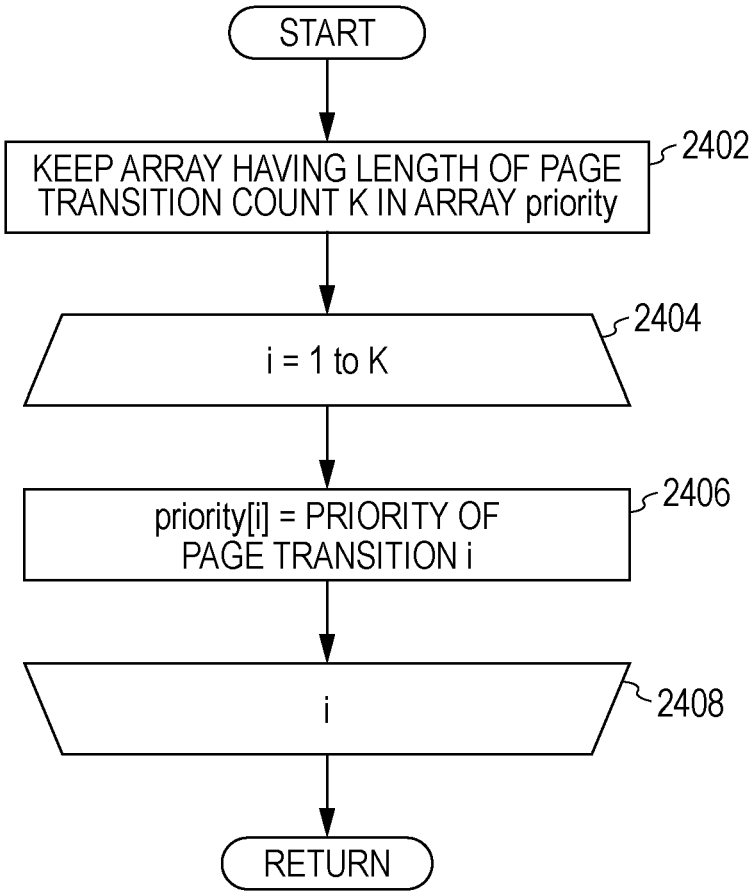

START
KEEP ARRAY HAVING LENGTH OF PAGE TRANSITION COUNT K IN ARRAY priority
2402
i = 1 to K
2404
priority[i] = PRIORITY OF PAGE TRANSITION i
2406
i
2408
RETURN

FIG. 25

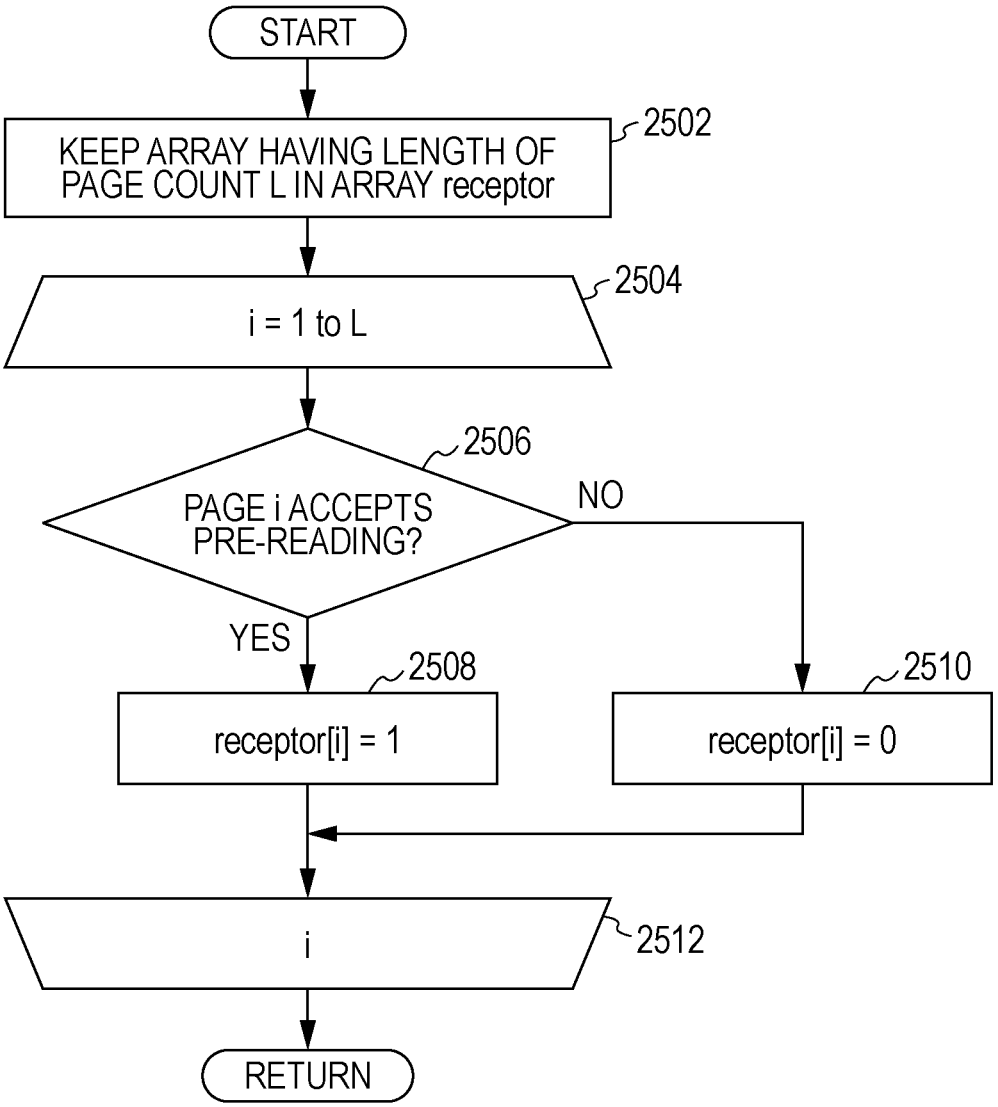

START
KEEP ARRAY HAVING LENGTH OF PAGE COUNT L IN ARRAY receptor
2502
i = 1 to L
2504
PAGE i ACCEPTS PRE-READING?
2506
NO
YES
receptor[i] = 1
2508
receptor[i] = 0
2510
i
2512
RETURN

FIG. 26

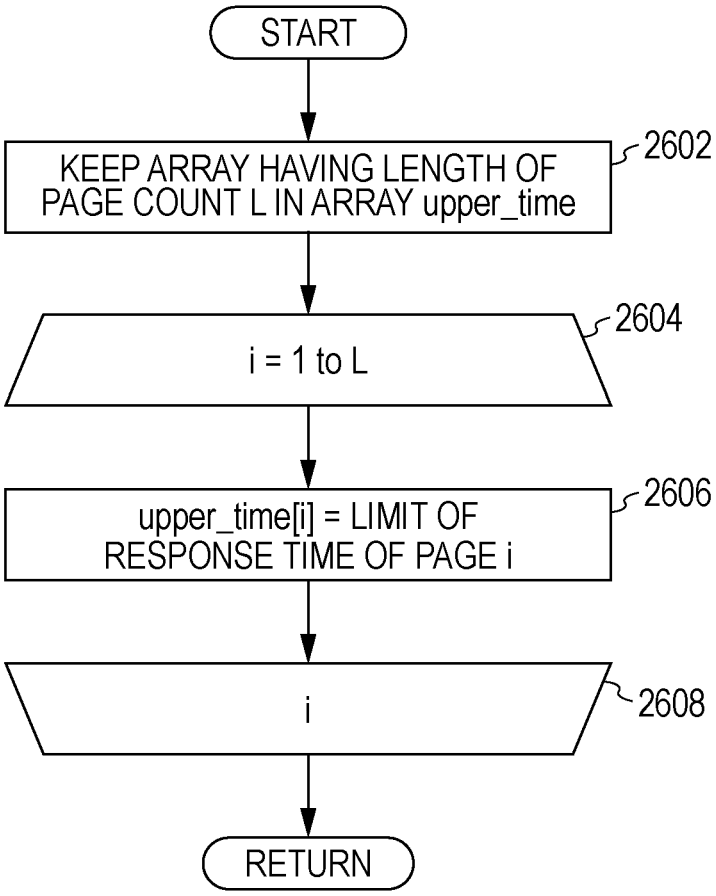

START
KEEP ARRAY HAVING LENGTH OF PAGE COUNT L IN ARRAY upper_time
2602
i = 1 to L
2604
upper_time[i] = LIMIT OF RESPONSE TIME OF PAGE i
2606
i
2608
RETURN

FIG. 27

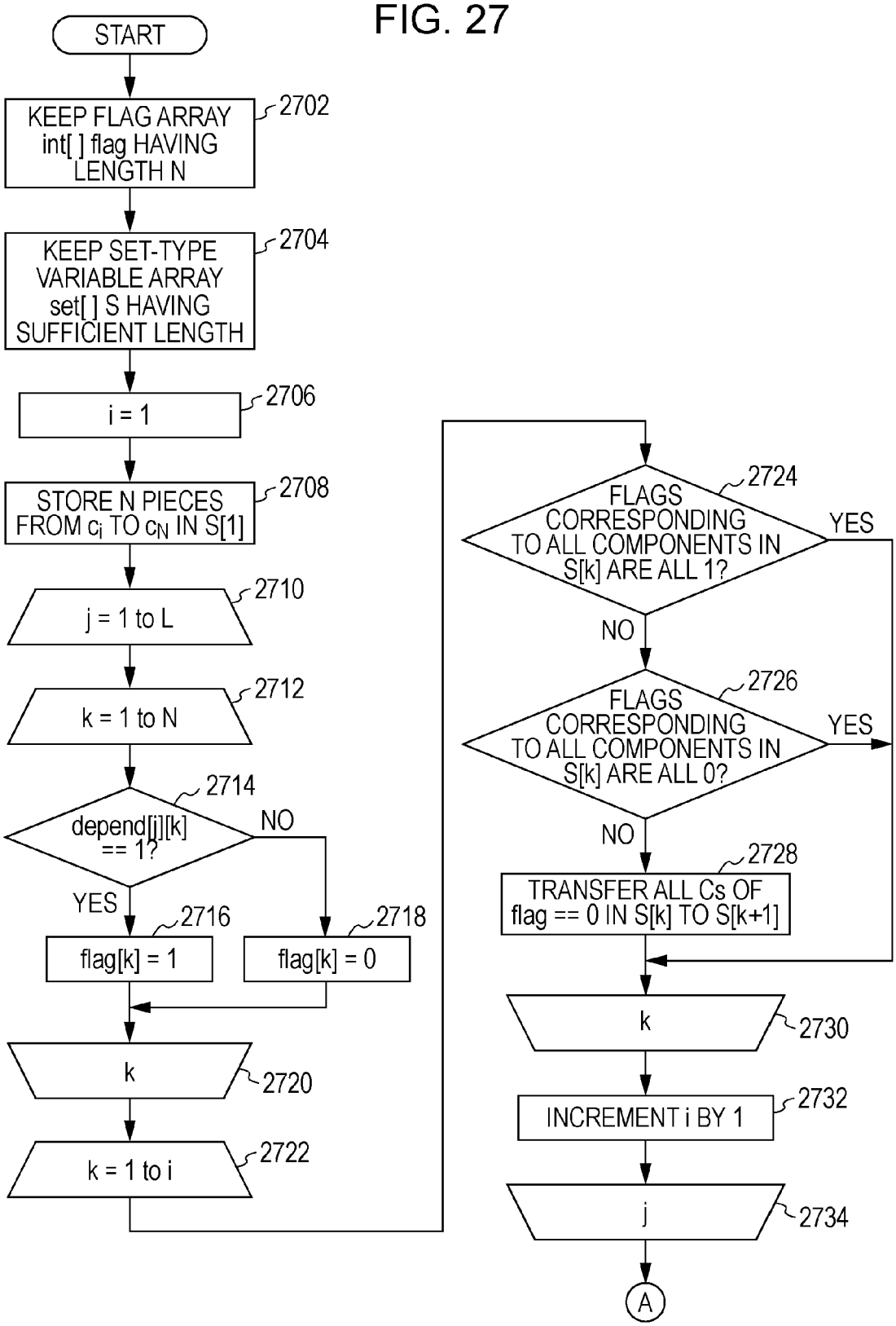

START
KEEP FLAG ARRAY int[ ] flag HAVING LENGTH N
2702
KEEP SET-TYPE VARIABLE ARRAY set[ ] S HAVING SUFFICIENT LENGTH
2704
i = 1
2706
STORE N PIECES FROM c_i TO c_N IN S[1]
2708
j = 1 to L
2710
k = 1 to N
2712
depend[j][k] == 1?
2714
NO
YES
flag[k] = 1
2716
flag[k] = 0
2718
k
2720
k = 1 to i
2722
FLAGS CORRESPONDING TO ALL COMPONENTS IN S[k] ARE ALL 1?
2724
YES
NO
FLAGS CORRESPONDING TO ALL COMPONENTS IN S[k] ARE ALL 0?
2726
YES
NO
TRANSFER ALL Cs OF flag == 0 IN S[k] TO S[k+1]
2728
k
2730
INCREMENT i BY 1
2732
j
2734
A

FIG. 28

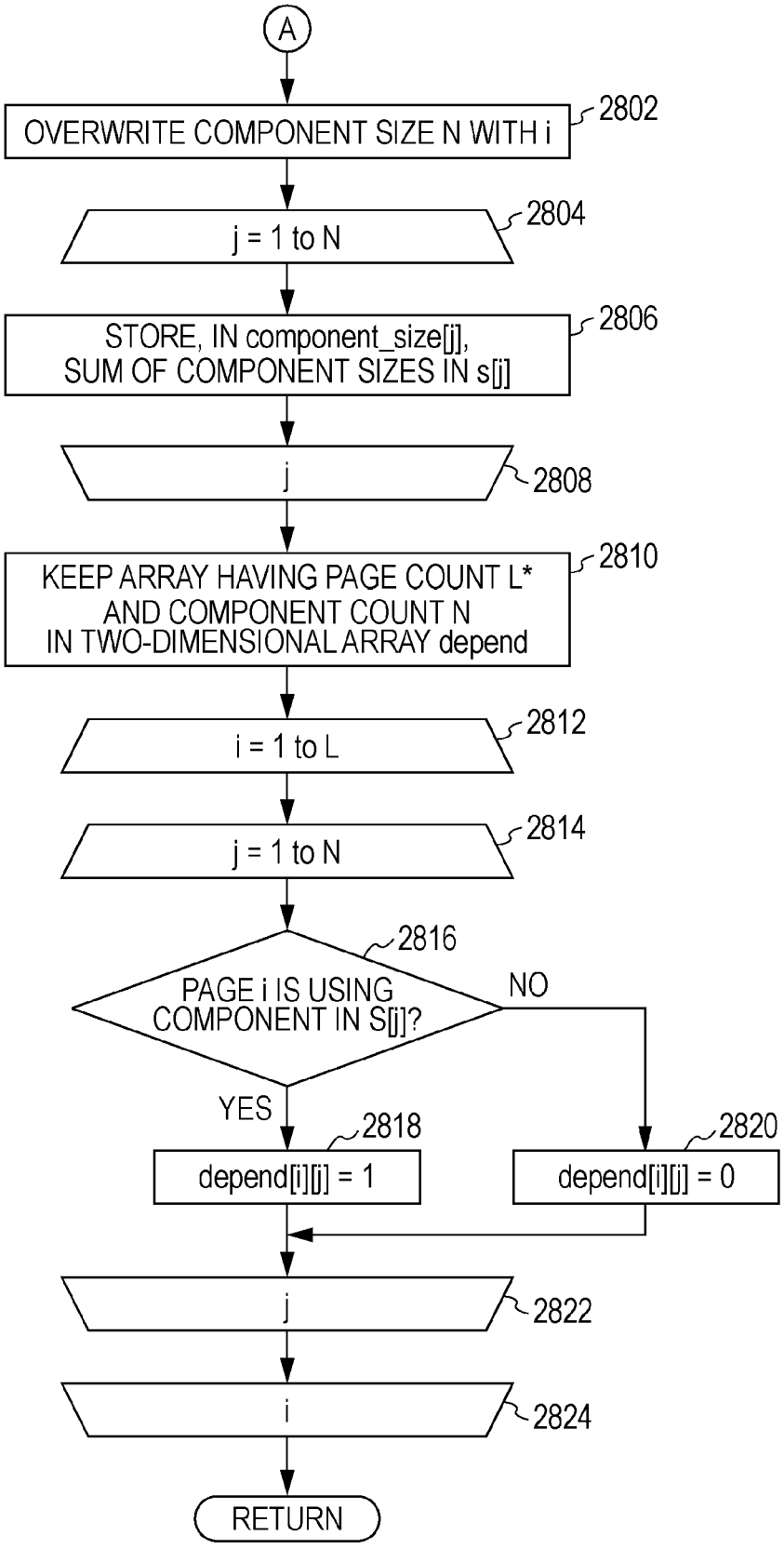

A
OVERWRITE COMPONENT SIZE N WITH i
2802
j = 1 to N
2804
STORE, IN component_size[j],
SUM OF COMPONENT SIZES IN s[j]
2806
j
2808
KEEP ARRAY HAVING PAGE COUNT L*
AND COMPONENT COUNT N
IN TWO-DIMENSIONAL ARRAY depend
2810
i = 1 to L
2812
j = 1 to N
2814
PAGE i IS USING
COMPONENT IN S[j]?
2816
NO
YES
depend[i][j] = 1
2818
depend[i][j] = 0
2820
j
2822
i
2824
RETURN

FIG. 29

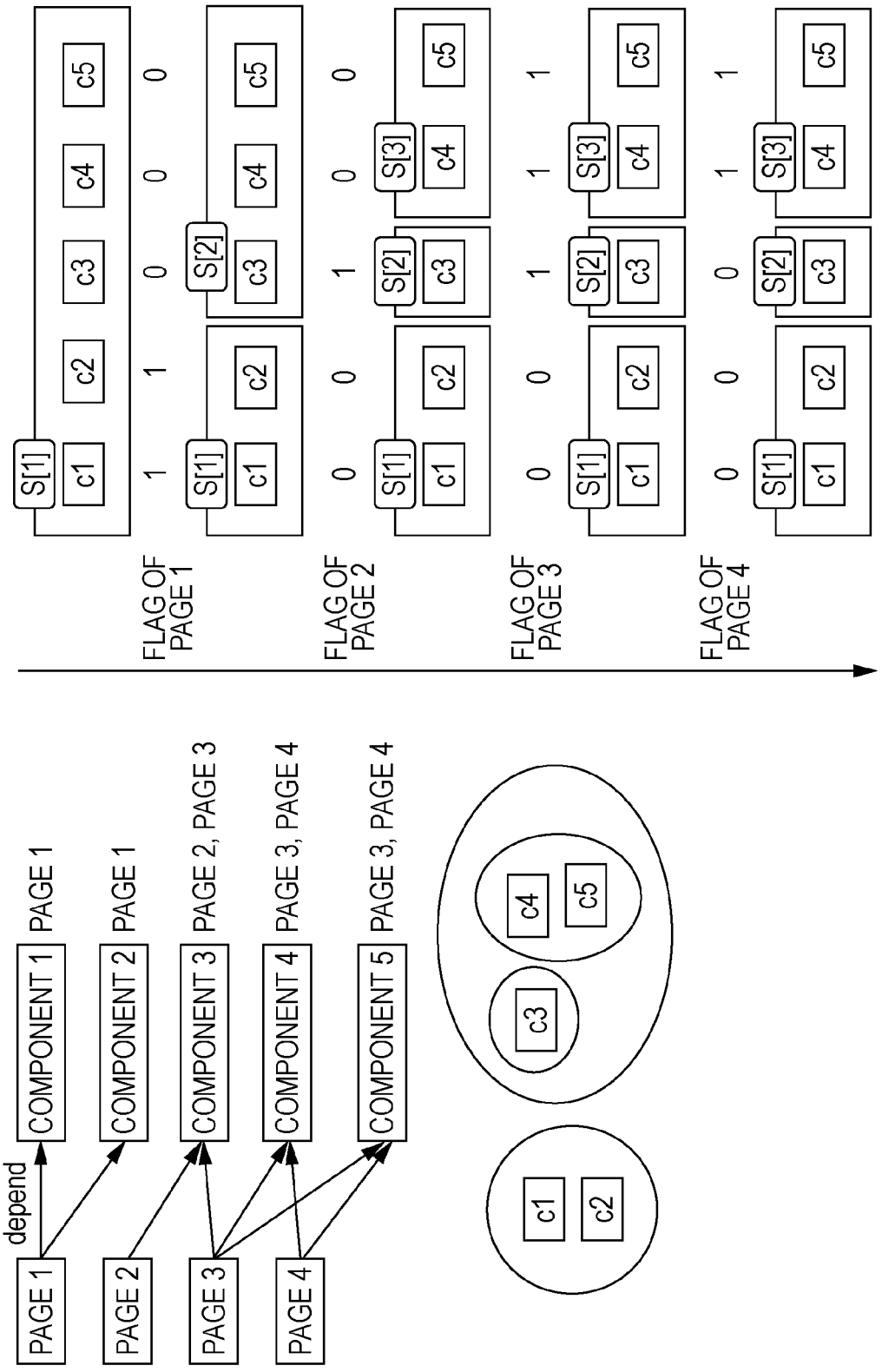

PAGE 1
PAGE 2
PAGE 3
PAGE 4
depend
COMPONENT 1
COMPONENT 2
COMPONENT 3
COMPONENT 4
COMPONENT 5
PAGE 1
PAGE 1
PAGE 2, PAGE 3
PAGE 3, PAGE 4
PAGE 3, PAGE 4
c1
c2
c3
c4
c5
FLAG OF PAGE 1
FLAG OF PAGE 2
FLAG OF PAGE 3
FLAG OF PAGE 4
S[1]
S[2]
S[3]
1 1 0 0 0
0 0 1 0 0
0 0 1 1 1
0 0 0 1 1

FIG. 30

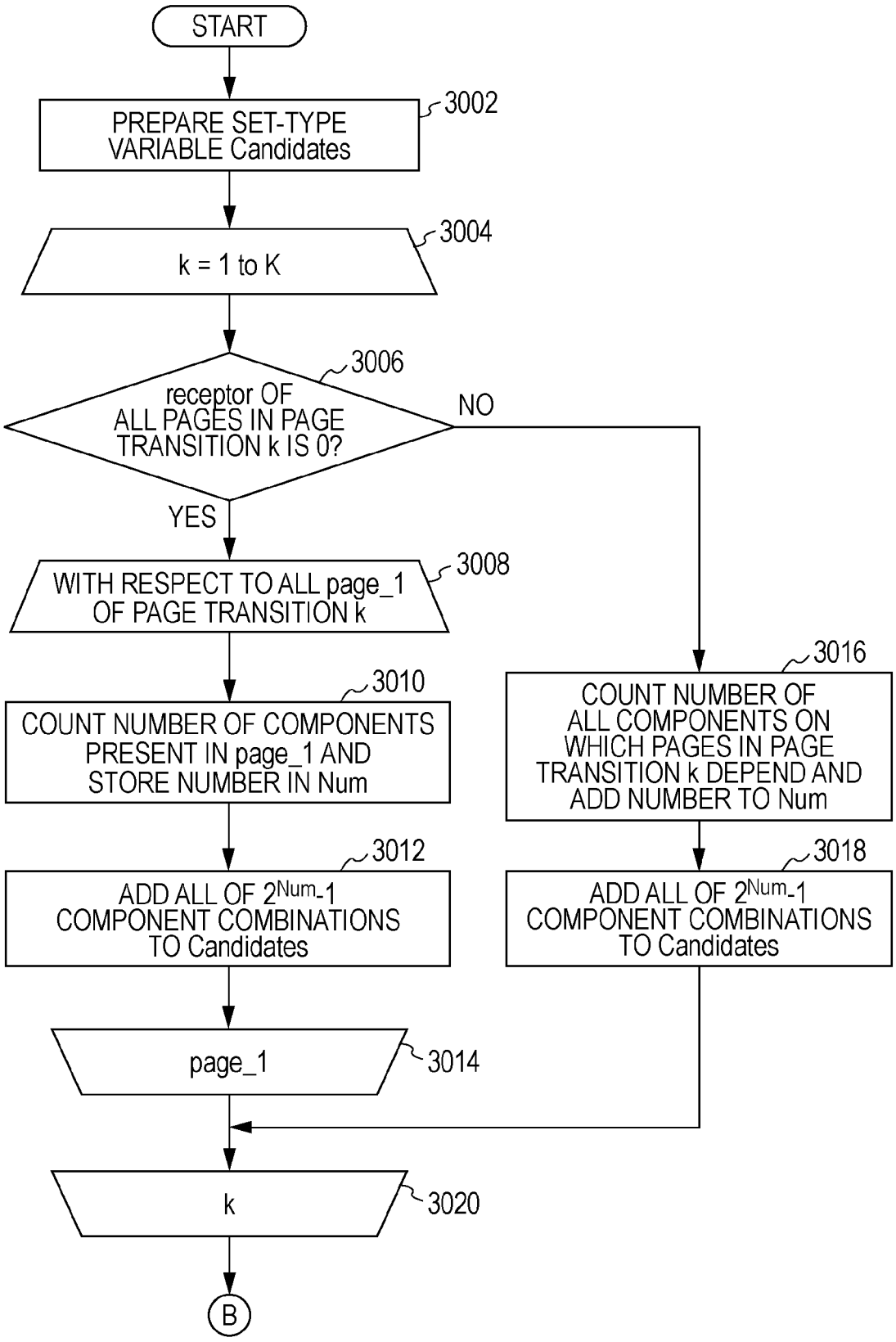

START
PREPARE SET-TYPE VARIABLE Candidates
3002
k = 1 to K
3004
receptor OF ALL PAGES IN PAGE TRANSITION k IS 0?
3006
NO
YES
WITH RESPECT TO ALL page_1 OF PAGE TRANSITION k
3008
COUNT NUMBER OF COMPONENTS PRESENT IN page_1 AND STORE NUMBER IN Num
3010
ADD ALL OF 2^{Num}-1 COMPONENT COMBINATIONS TO Candidates
3012
COUNT NUMBER OF ALL COMPONENTS ON WHICH PAGES IN PAGE TRANSITION k DEPEND AND ADD NUMBER TO Num
3016
ADD ALL OF 2^{Num}-1 COMPONENT COMBINATIONS TO Candidates
3018
page_1
3014
k
3020
B

FIG. 31

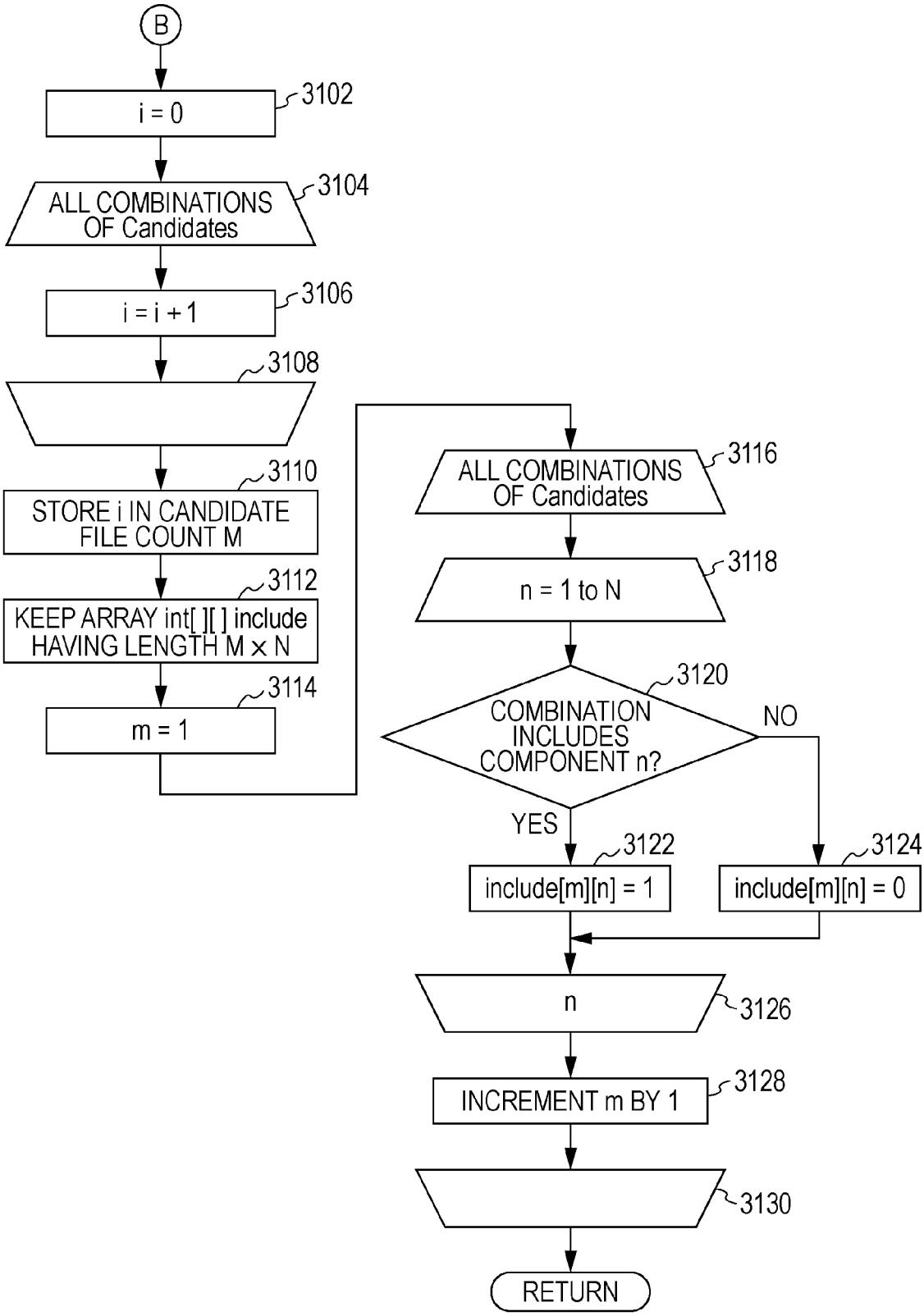

B
i = 0
3102
ALL COMBINATIONS OF Candidates
3104
i = i + 1
3106
3108
STORE i IN CANDIDATE FILE COUNT M
3110
KEEP ARRAY int[ ][ ] include HAVING LENGTH M × N
3112
m = 1
3114
ALL COMBINATIONS OF Candidates
3116
n = 1 to N
3118
COMBINATION INCLUDES COMPONENT n?
3120
NO
YES
include[m][n] = 1
3122
include[m][n] = 0
3124
n
3126
INCREMENT m BY 1
3128
3130
RETURN

FIG. 32

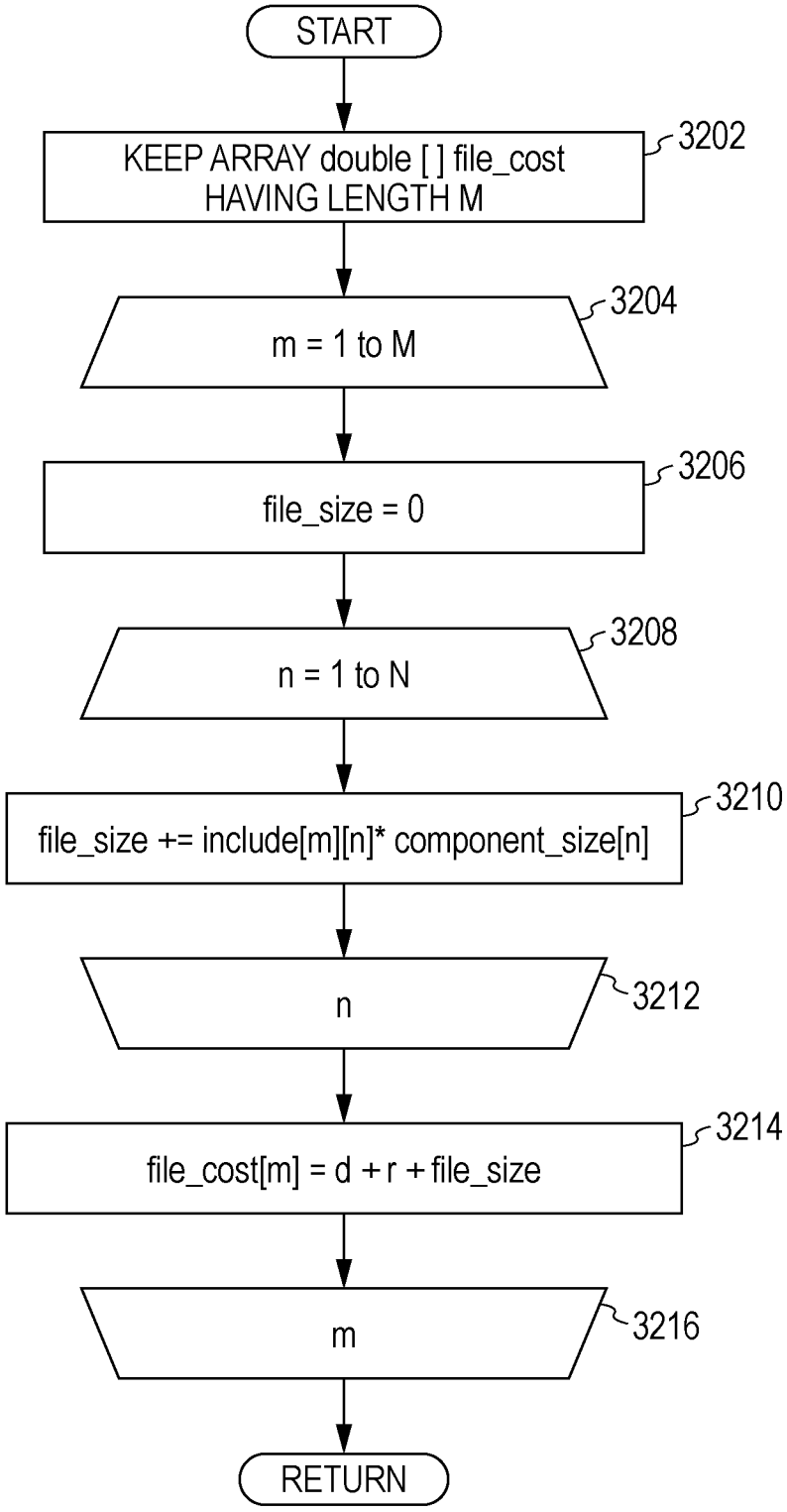

START
KEEP ARRAY double [ ] file_cost HAVING LENGTH M
3202
m = 1 to M
3204
file_size = 0
3206
n = 1 to N
3208
file_size += include[m][n]* component_size[n]
3210
n
3212
file_cost[m] = d + r + file_size
3214
m
3216
RETURN

FIG. 33

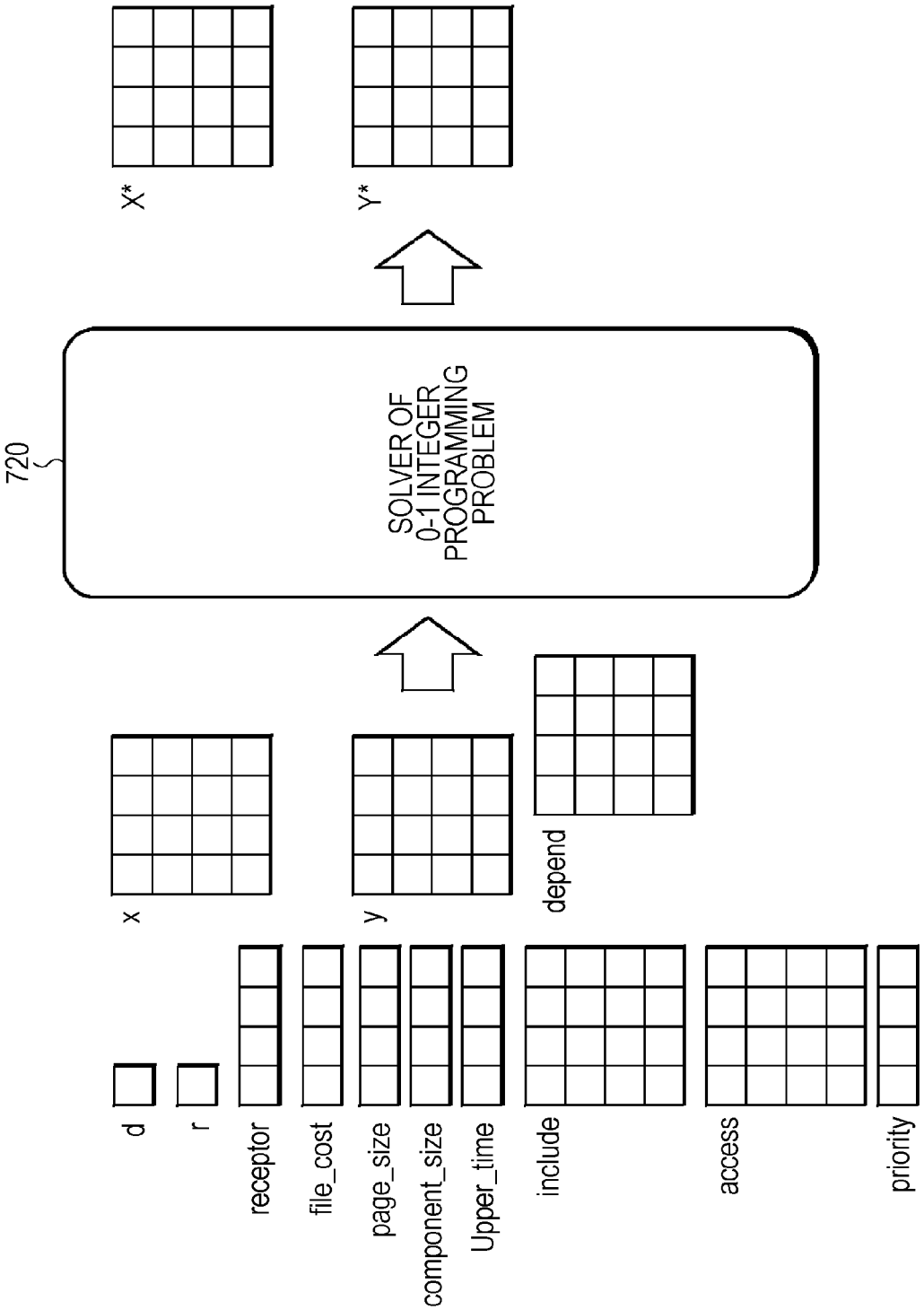

720
SOLVER OF 0-1 INTEGER PROGRAMMING PROBLEM
X*
Y*
x
y
depend
d
r
receptor
file_cost
page_size
component_size
Upper_time
include
access
priority

FIG. 34

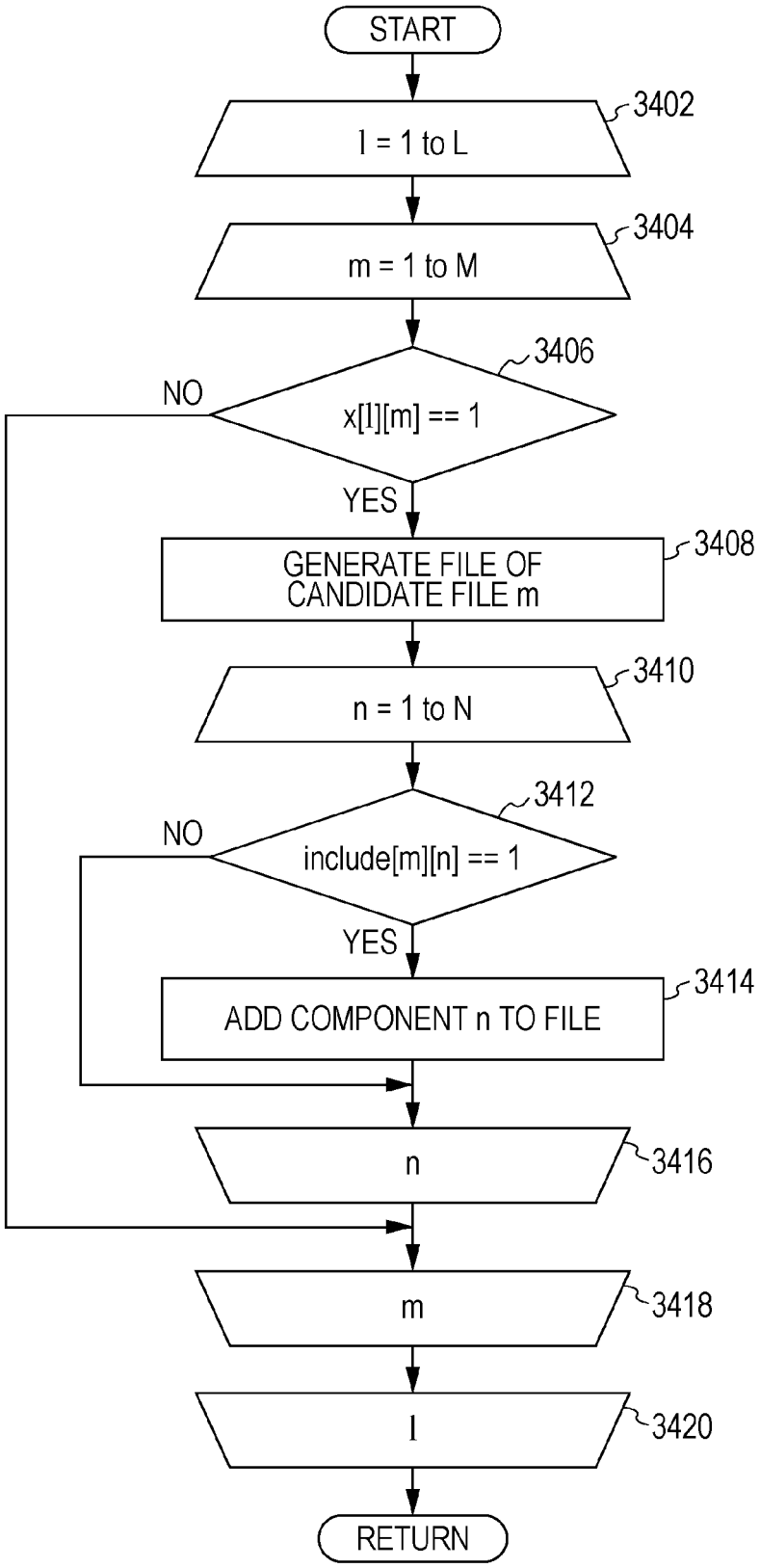

START
3402
l = 1 to L
3404
m = 1 to M
3406
NO
x[l][m] == 1
YES
3408
GENERATE FILE OF CANDIDATE FILE m
3410
n = 1 to N
3412
NO
include[m][n] == 1
YES
3414
ADD COMPONENT n TO FILE
3416
n
3418
m
3420
l
RETURN

FIG. 35

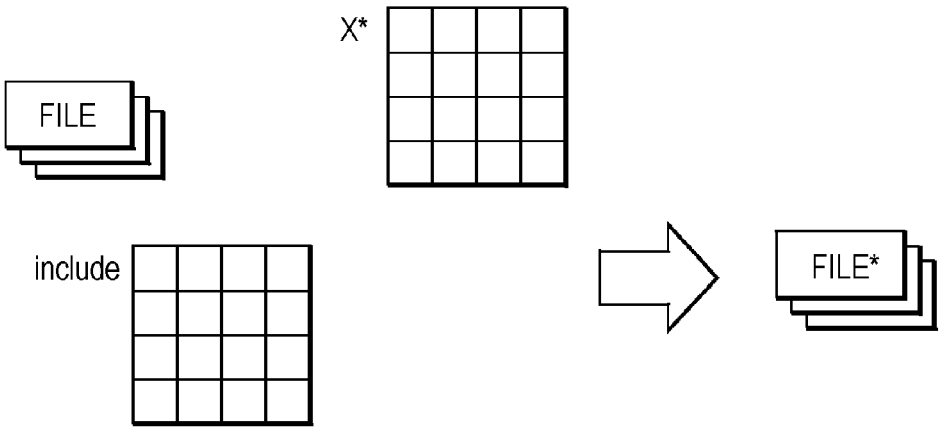


FIG. 36

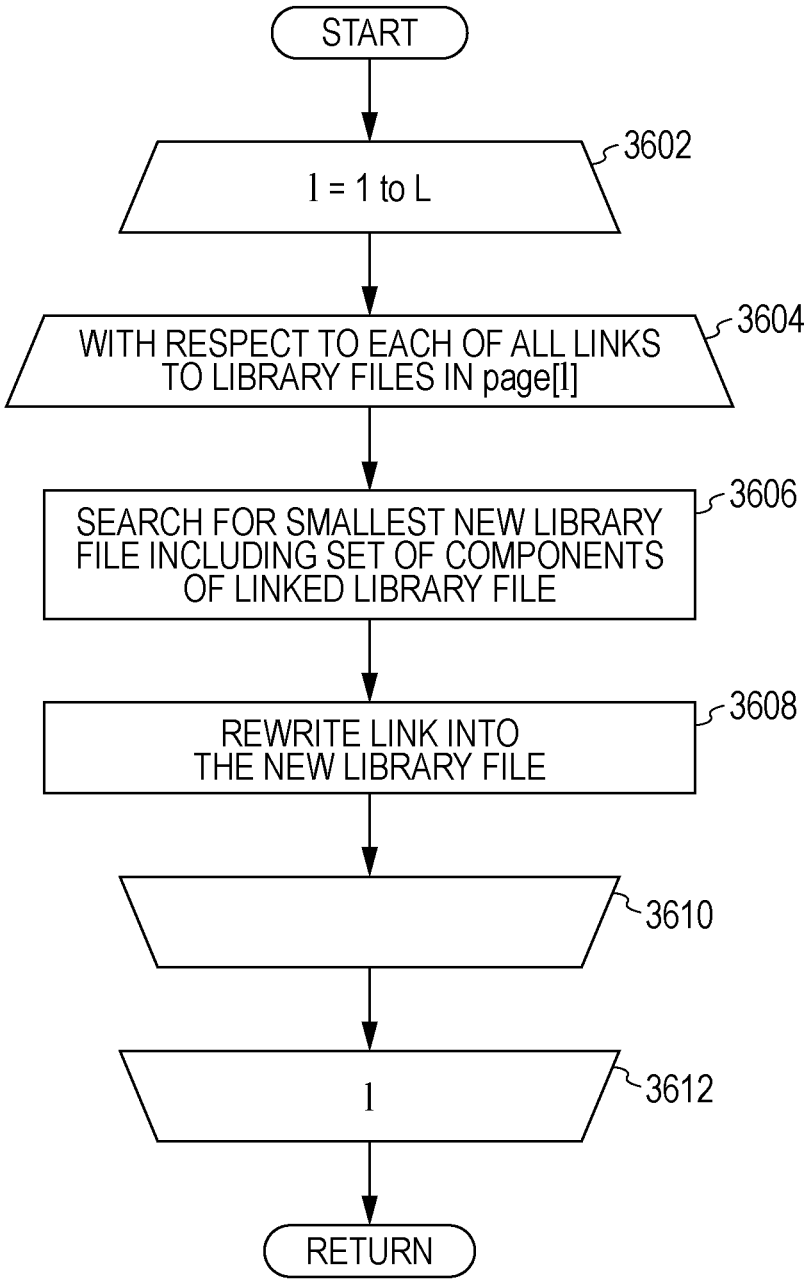
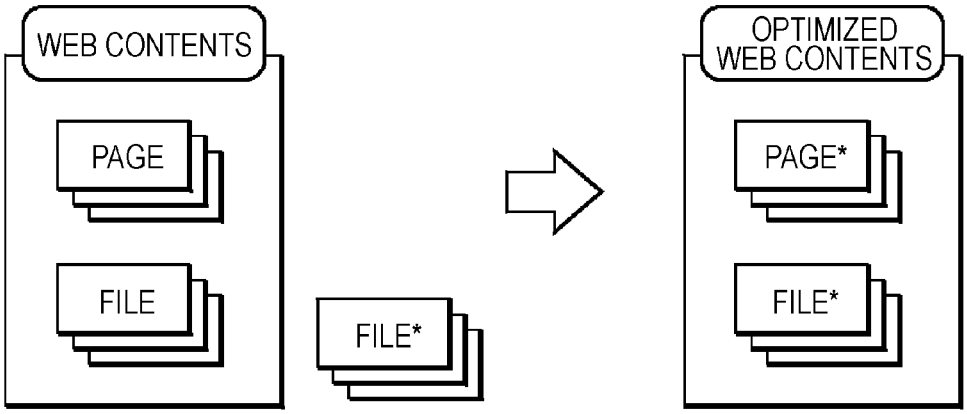

START
3602
l = 1 to L
3604
WITH RESPECT TO EACH OF ALL LINKS TO LIBRARY FILES IN page[l]
3606
SEARCH FOR SMALLEST NEW LIBRARY FILE INCLUDING SET OF COMPONENTS OF LINKED LIBRARY FILE
3608
REWRITE LINK INTO THE NEW LIBRARY FILE
3610
3612
l
RETURN

FIG. 37


WEB CONTENTS
PAGE
FILE
FILE*
OPTIMIZED WEB CONTENTS
PAGE*
FILE*

SYSTEM, METHOD, AND PROGRAM FOR GENERATING WEB PAGE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority under 35 U.S.C. §119 from Japanese Patent Application No. 2010-214942 filed Sep. 27, 2010 the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

I. Field of the Invention

The present invention relates to a technique for generating a web page that is viewed through an Internet browser. More specifically, the invention relates to a technique for reducing the load time required when viewing a web page.

II. Related Art

Web pages viewed on the Internet have been very commonly used as information sending means, advertizing means, or information gathering means. Recently, there has been an appearance of high-functionality, complicated web pages that not only are intended to be viewed, but also to include many pages and images having dynamic functions using JavaScript(R).

For such complicated web pages including many contents, it takes time to load their top page through a browser. Certain statistics suggest that users exit a page if it takes eight seconds or more to load the page.

Known attempts to reduce the load time of pages include a technology that dynamically causes a client to request necessary files at run time, connects the files on the server, and transfers the connected file. While this technology has an advantage in that optimization is performed individually for each client, it has disadvantages in that a special procedure must be followed in generating a web page, and in that an overhead occurs on the server at run time.

Other known technologies include one that previously connects files to be loaded on a page; however, this technology disadvantageously can perform only rough optimization such as connection of all files or connection of only files related to a particular page.

FIG. **1** shows a state-of-the-art example of a simple process in which multiple files are combined to improve the response time. Specifically, when an HTML file **102** is referring to JavaScript(R) files **104**, **106**, and **108**, the files **104**, **106**, and **108** are connected to a file **110** using an existing tool. An HTML file **112** refers to the combined file **110**. This change improves the response time. Known existing tools having such a function include Dojo custom build and Scriptalizer.

FIG. **2** shows an example of response time improvement where each page is brought into focus. In FIG. **2**, a client **1** browses HTML files **202** and **206** sequentially. Files **204** and **208** including JavaScript(R) are sequentially loaded accordingly.

On the other hand, a client **2** is only required to download a file including only necessary function C( ) and function D( ). This is done rapidly.

Since the client **1** was originally intended to browse only the HTML file **202**, it is useless that the client **1** has loaded function D( ). Further, the inclusion of function C( ) in both the files **204** and **206** complicates source code management. For example, if function C( ) in the file **204** is changed, function C( ) in file **206** must be changed as well.

FIG. **3** shows an example of response time improvement where an HTML file **302** is brought into focus. In FIG. **3**, a client **1** browses HTML files **302** and **306** sequentially. Files **304** and **308** including JavaScript(R) are sequentially loaded accordingly.

On the other hand, a client **2** uses the HTML file **306** loaded and cached by the client **1**, but downloads unnecessary function A( ) and B( ) through the HTML file **306**.

FIG. **4** shows an example in which accesses are balanced. In this example, an HTML file **402** refers to files **404** and **408**, while an HTML file **406** refers to files **408** and **410**. The HTML file **402** is accessed frequently, while the HTML file **406** is accessed moderately. Function C( ) must be included in the file **408**.

Use of such an approach can balance accesses to the pages to improve the load speed.

However, an actual web application page as shown in FIG. **5** includes many pages, and some of the pages include JavaScript(R). Accordingly, optimization of JavaScript(R) connection in a certain page can result in reductions in performance of other pages.

In an attempt to use a response improvement approach as described above, consideration must be made to an exponential combination of an HTML file, a JavaScript(R) file, and a JavaScript(R) function. Accordingly, such an approach cannot be allowed in terms of computational complexity.

Known related art examples to address the above-mentioned problem include the following ones. Japanese Unexamined Patent Application Publication No. 2001-34527 discloses a method including: holding a frame management sheet where multiple combination patterns of frame placement and contents are described and defined as one file, on a WWW browser as initial display information; reading a frame display definition file; displaying contents described on the frame display definition file; when receiving a content change request from the operator, determining whether there are frames having the same placement, by referring to the frame management sheet; making a request for only contents whose placement is to be changed, to the WWW server; and when receiving changed contents from the WWW server, displaying the changed contents to speed up screen display.

Japanese Patent Application Publication No. 2001-356957 discloses an information display terminal apparatus including: browsing means that displays information on a screen; server means that stores necessary page data to display the information; and cache means that speeds up information display performed by the browsing means by holding part of the stored page data. In updating page data within the server means, an external device directly writes updated data to the cache means.

Japanese Patent Application Publication No. 2002-222165 discloses a method including, in displaying (viewing) an HTML document including multiple images in the display area, preferentially receiving images included in the displayable area (viewing area) over other images regardless of the placement order (appearance order) in the HTML document or the like and displaying the images rapidly so as to speed up the display of the HTML document involving image display and reduce the image display waiting time to increase viewing operability.

Japanese Patent Application Publication No. 2009-110216 discloses a server apparatus that designates a frequently viewed URL in an URL importance table with the URL given higher importance and thus changes the priority in a screen cache priority table in accordance with the importance of the designated URL and that stores drawing data in a cache memory for the drawing data. This related-art example also discloses a client apparatus that, when running a web browser,

reads drawing data of a frequently viewed URL with high priority from a cache memory for the drawing data and displays the drawing data.

Japanese Patent Application Publication No. 2010-170182 discloses a data display apparatus including browser function means which is connected to a data accumulation apparatus via a network and which displays data for display accumulated in the data accumulation apparatus. A browser cache determination unit within the browser function means determines whether data for display requested by the user is stored in the browser cache area. If the data is not stored, the data is obtained from an application server within the data accumulation apparatus so as to speed up data display.

While any of the above-mentioned related art examples make some contribution to increasing the speed of page display through a browser, use of these related art examples to improve the response time of complicated web pages including many pages, a script, a function, and an image can cause a combinatorial explosion which is difficult to handle.

SUMMARY OF INVENTION

One aspect of the invention includes a computer-implemented method for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser. The method includes the steps of: extracting dependencies between (i) pages, (ii) files, and (iii) components of the web page stored in a storage unit of the computer, measuring (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size, estimating load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size, generating an integer programming problem, where the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating a (i) dependency, (ii) an inclusion relationship and (iii) a loading relationship in the form of a 0-1 table, solving the integer programming problem using a solver, reconfiguring a library file from a solution obtained by the solver, reconfiguring the web page by replacing a link to the library file of each page with a link to the reorganized library file, and where, at least one step is carried out using a computer device.

Another aspect of the invention includes an article of manufacture tangibly embodying computer readable instructions which, when implemented, cause a computer to carry out the steps of a method for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser, where the method includes the steps of: extracting dependencies between (i) pages, (ii) files, and (iii) components of the web page, measuring (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size, estimating load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size, generating an integer programming problem, where the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating (i) a dependency, (ii) an inclusion relationship, and (iii) a loading relationship in the form of a 0-1 table, solving the integer programming problem using a solver, reconfiguring a library file from a solution obtained by the solver, and reconfiguring the web page by replacing a link to the library file of each page with a link to the reorganized library file.

Yet another aspect of the invention includes a system for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser. The system includes: a storage unit that stores (i) pages, (ii) files, and (iii) components of the web page, a dependency extraction module that extracts dependencies between (i) pages, (ii) files, and (iii) components of the web page stored in the storage unit, a measurement module that measures (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size, an estimated load time calculation module that estimates load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size, an integer programming problem generation module that generates an integer programming problem, where the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating a (i) dependency, (ii) an inclusion relationship, and (iii) a loading relationship in the form of a 0-1 table, a solver that has the function of solving the integer programming problem, a reconfiguration module that reorganizes a library file from a solution obtained by the solver, and a reconfiguration module that reorganizes the web page by replacing a link to the library file of each page with a link to the reorganized library file.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a drawing illustrating an example of response time improvement according to the related art.

FIG. **2** is a drawing illustrating an example of a possible response time improvement technology.

FIG. **3** is a drawing illustrating an example of a possible response time improvement technology.

FIG. **4** is a drawing illustrating an example of a possible response time improvement technology.

FIG. **5** is a drawing schematically illustrating the complexity of an actual web application.

FIG. **6** is a block diagram illustrating an example of hardware according to an embodiment of the present invention.

FIG. **7** is a diagram illustrating functional logic blocks according to this embodiment.

FIG. **8**(*a*) is a drawing illustrating the connections between pages, files, and components as an integer programming problem.

FIG. **8**(*b*) is a drawing illustrating the connections between pages, files, and components as an integer programming problem.

FIG. **9**(*a*) is a diagram illustrating a browser cache effect.

FIG. **9**(*b*) is a diagram illustrating a browser cache effect.

FIG. **10** is a diagram illustrating the connections between clients, pages, and files.

FIG. **11**(*a*) is a diagram illustrating conversion from quadratic programming to linear programming.

FIG. **11**(*b*) is a diagram illustrating conversion from quadratic programming to linear programming.

FIG. **12**(*a*) is a diagram illustrating an aspect where the same types of components are concatenated by using a combination of dependencies to reduce the number of components.

FIG. **12**(*b*) is a diagram illustrating an aspect where the same types of components are concatenated by using a combination of dependencies to reduce the number of components.

FIG. **13** is a diagram illustrating an aspect where a candidate search file is generated from a value representing whether a page transition, dependency, or speculative load is allowed.

FIG. **14** is a diagram illustrating an aspect where a candidate search file is generated from a value representing whether a page transition, dependency, or speculative load is allowed.

FIG. **15** is a drawing illustrating prioritization of a particular transition pattern using typical clients and their priority.

FIG. **16** is a flowchart illustrating the process of solving a linear programming problem obtained by relaxing an integer programming problem.

FIG. **17** is a flowchart schematically illustrating the entire process according to this embodiment.

FIG. **18** is a flowchart illustrating a network delay value storage process.

FIG. **19** is a flowchart illustrating a transfer efficiency value storage process.

FIG. **20** is a flowchart illustrating the process of storing page sizes in double[ ] page_size.

FIG. **21** is a flowchart illustrating the process of storing component sizes in double[ ] component_size.

FIG. **22** is a flowchart illustrating the process of extracting dependencies and storing them in int[ ][ ] depend.

FIG. **23** is a flowchart illustrating the process of storing page transitions in int[ ][ ] access.

FIG. **24** is a flowchart illustrating the process of storing the priority of page transitions in double[ ] priority.

FIG. **25** is a flowchart illustrating the process of storing a determination as to whether each page accepts pre-reading of another page in double[ ] receptor.

FIG. **26** is a flowchart illustrating the process of storing the upper limit of the response time in double[ ] upper_time.

FIG. **27** is a flowchart illustrating the process of concatenating the same type of components using a combination of dependencies to reduce the number of components.

FIG. **28** is a flowchart illustrating the process of concatenating the same type of components using a combination of dependencies to reduce the number of components.

FIG. **29** is a schematic diagram illustrating an aspect of the process of concatenating the same type of components using a combination of dependencies to reduce the number of components.

FIG. **30** is a flowchart illustrating the process of generating candidate search files and storing them in int[ ][ ] include.

FIG. **31** is a flowchart illustrating the process of generating candidate search files and storing them in int[ ][ ] include.

FIG. **32** is a flowchart illustrating the process of estimating the load times of the generated candidate search files and storing them in double[ ] file_cost.

FIG. **33** is a diagram schematically illustrating an input and an output of a solver.

FIG. **34** is a flowchart illustrating the process of reconfiguring a library file from an output x*.

FIG. **35** is a diagram schematically illustrating the process of reconfiguring a library file from an output x*.

FIG. **36** is a flowchart illustrating the process of replacing a link to the library file of each page with a link to a newly generated library file.

FIG. **37** is a diagram schematically illustrating the process of replacing a link to the library file of each page with a link to a newly generated library file.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

It is an object of the present invention to provide a technique to improve response time which is applicable to complicated web pages including many pages, a script, a function, and an image.

Considering the relationships between a great number of pages and a great number of files, the present invention provides a technique that reorganizes a web page so that the response time required when viewing the web page is improved.

A page used herein typically refers to a web unit accessed by a client and generally depends on some components. A page includes some files in order to use components on which the page depends. A component refers to a web content unit and is, for example, a JavaScript(R) function, a collection of JavaScript(R) code, a collection of css lines, an image, or the like. A file typically refers to a JavaScript(R) file, a css file, a css sprite (a technology that stores multiple images in one image and cuts an area from the one image and displays the resulting image on an HTML), or the like.

In a processing program according to the present invention, first, the dependencies between pages and components of a web page whose response time is desired to be improved are extracted.

The next step is to measure a network delay value, a transfer efficiency value, page sizes, and component sizes. In principle, this process is also automatically performed by the processing program.

The next step is to set page transition patterns and their priority and the upper limit of the response time of each page. In principle, this process is performed by an operator who performs a web page response time improvement process.

The next step is to concatenate the same type of components using a combination of the extracted dependencies in accordance with the processing program. At this time, considering the concatenated components as a new component, information such as the component size is updated.

The next step is to generate a candidate search file in accordance with the processing program. Subsequently, the estimated load time of the generated candidate file is calculated in accordance with the processing program.

The next step is to generate an integer programming problem in accordance with the processing program. Specifically, the web page is analyzed, and a dependency (depend) and an inclusion relationship (include) are generated in the form of a 0-1 table. Further, a loading relationship (x) is generated in the form of a 0-1 table.

At that time, a constraint condition "some files read by a page i must provide the page i with all components on which the page i depends" is imposed on the integer programming problem. The integer programming problem is then formulated so that the sum of the download times of the pages and files is minimized, and a solver is allowed to solve the integer programming problem.

A library file is reorganized from the obtained solution in accordance with the processing program. A link to the library file of each page is rewritten into a link to the reorganized library file.

According to the present invention, a web page response time improvement process results in an integer programming problem. Thus, even a complicated web page can be reorganized with reasonable computational complexity so that the response time is improved.

An embodiment of the present invention will be described with reference to the accompanying drawings. It should be

understood that this embodiment is intended to describe a preferred aspect of the present invention and is not intended to limit the scope of the invention. Through the drawings below, same reference signs designate same components unless otherwise specified.

FIG. **6** shows a block diagram of computer hardware for realizing a system configuration and processes according to this embodiment. In FIG. **6**, a CPU **604**, a main memory (RAM) **606**, a hard disk drive (HDD) **608**, a keyboard **160**, a mouse **612**, and a display **614** are connected to a system bus **602**. The CPU**604** is preferably based on a 32-bit or 64-bit architecture and can be, for example, Pentium™ 4 or Core™ 2 DUO available from Intel Corporation or Athlon™ available from Advanced Micro Devices, Inc. The main memory **606** has a capacity preferably not less than 1 GB, more preferably not less than 2 GB.

The hard disk drive **608** has an operating system installed thereon. The operating system can be of any type conforming to the CPU **604**, such as Linux™, Windows™ 7, Windows XP™, or Windows™ 2003 server available from Microsoft Corporation or Mac OS™ available from Apple Inc.

Also installed on the hard disk drive **608** is a program for causing the system to operate as a web server, such as Apache. This program is loaded into the main memory **606** when the system is started.

Further, the hard disk drive **608** is storing a web page which is desired to be viewed through a browser with an improved response time, and the contents of the web page. A web page used herein is typically a web unit accessed by a client and generally depends on some components. A web page also includes some files in order to use the components on which it depends. A component is a unit of web content and refers to, for example, a JavaScript(R) function, a collection of JavaScript(R) code, a collection of css lines, an image, and the like. A file typically refers to a JavaScript(R) file, css file, css sprite, or the like.

The hard disk drive **608** also includes a web page dependency extraction module, a component concatenation module, a file search module, an integer programming problem generation module, and an integer programming solver. These modules are loaded into the main memory **606** by the operating system as necessary and executed by the CPU **604** or the like. These modules will be described in more detail with reference to FIG. **7**.

The keyboard **610** and the mouse **612** are used to operate graphic objects displayed on the display **614**, such as icons, task bars, and windows, in accordance with a graphic user interface provided by the operating system.

The display **614** is preferably a 32-bit true color LCD monitor with a resolution of 1024×768 or more, but not limited thereto.

The communication interface **616** is preferably connected to a network in accordance with an Ethernet(R) protocol. Using a function provided by Apache through a client computer (not shown), the communication interface **616** receives a process request in accordance with a communication protocol such as TCP/IP or returns a process result to a client computer (not shown).

Next, referring to FIG. **7**, the functions of files and function modules stored in the hard disk drive **608** will be described in relation to the present invention. Contents **702** include the contents of the web page whose response time is desired to be improved, that is, the above-mentioned pages, files, and components.

A dependency extraction module **704** reads pages and files from the contents **702** and extracts the dependency therebetween.

Dependency used herein refers to a relationship in which the contents of a file are used in a page through a link such as ~ or a call such as <script src="xyz/abc.js" type="text/javascript"></script>, <img src="xyz/abc.gif">. Assuming that the components are Javascript functions and the files are Javascript files, a sample HTML file to be described later depends on, for example, a component function012(a,b,c) through a file test03.js.

According to information obtained from the dependency extraction module **704**, a component concatenation module **706** concatenates components included in the contents **702** and writes the concatenated component to the hard disk drive **608** as an intermediate file **708** so as to use it later. The component concatenation module will be described later.

A parameter setting module **710** has the function of showing a panel, preferably on the display **614**, to the operator so that the operator can set page transition patterns and their priority and the upper limit of the response time of each pattern.

A candidate search file generation module **712** generates a candidate search file while referring to the contents **702** and the intermediate file **708**, as well as the information set by the parameter setting module **710** as necessary. It then writes the generated candidate search file to the hard disk drive **608** as an intermediate file **708** in order to use it later. A search file will also be described later.

A measurement module **714** measures a network delay value, a transfer efficiency value, a page size, and a component size while using the communication interface **616** as necessary.

An estimated load time calculation module **716** calculates an estimated load time using measurements obtained by the measurement module **714** while referring to the settings made by the parameter setting module **710** in some cases. The estimated load time calculated can be stored in the main memory **606** or temporarily stored in the hard disk drive **608**.

An integer programming problem generation module **718** generates an equation representing an integer programming problem on the basis of the output of the estimated load time calculation module **716**. The integer programming problem equation generated will be described specifically.

A solver **720** solves the integer programming problem equation generated by the integer programming problem generation module **718**.

Using the output of the solver **720**, a reconfiguration module **722** generates updated contents **724** on the basis of the original contents **702** and the intermediate file **708**. The updated contents **724** allow the web page to be browsed with an optimized load time through a browser of a client computer, compared to the contents **702**.

Next, some features of the present invention will be described. A first feature is to convert an integer programming problem into an optimization problem and allow an optimization problem solver to solve the optimization problem. Where an existing tool is used, a component to which any page should be connected is not clear for a developer, as shown in FIG. **8**(*a*). Accordingly, the developer attempts to concatenate all components to one page.

On the other hand, the first feature of the present invention is shown in FIG. **8**(*b*). That is, as shown, a model or equation is generated in all selectable portions using optimization variables (x,y), and whether a page or file should be read is set by substituting 0-1 into these variables. Further, the time required for a page transition is defined using a cost function which varies depending on x,y, and x,y are derived so that the function is minimized.

A second feature is to introduce a browser cache effect. If no measure is taken, the cost of the same file is added to the cost function (the sum of the response times) multiple times, as shown in FIG. **9**(*a*). A measure in this regard is one shown in FIG. **9**(*a*). That is, the cost of the same file is added only once owing to a browser cache effect. This can avoid the cost from being added repeatedly.

A problem with this method is that an OR calculation is required. However, an OR calculation cannot be represented in a 0-1 integer programming problem. To solve this problem, typical clients are introduced, a set of continuously accessed pages is defined, and a variable Y is defined as follows:

Y=1: a file is read once or more during a page transition.

Y=0: a file is not read even once during a page transition.

For the variable Y to function as an OR, the following two constraint equations are introduced.

[Formula 1]

$$y_{km} \geq \frac{1}{L}\sum_{l=1}^{L} \text{access}(k, 1)\cdot x_{lm}(k = 1, \ldots, K, m = 1, \ldots, M)$$

$$y_{km} \geq \frac{1}{L}\sum_{l=1}^{L} \text{access}(k, 1)\cdot x_{lm} + 1 - \frac{1}{L}(k = 1, \ldots, K, m = 1, \ldots, M)$$

where K represents the number of clients; L represents the number of pages; M represents the number of files; and access(k,l) is 1 when a client k accesses page l and is otherwise 0.

In the upper one of the above-mentioned equations, Y must be 1 or more if 1 is present in access( )* x. An example is as follows:

$$Y(c1, \text{file2}) >= 1/3(\text{access}(c1, \text{page1})^{*}x(\text{page1}, \text{file2}) + \text{access}(c1, \text{page2})^{*}x(\text{page2}, \text{file2}) + \text{access}(c1, \text{page3})^{*}x(\text{page3}, \text{file2})) >= 1/3(1 + 1 + 0) >= 2/3$$

That is, Y is a 0-1 variable and therefore must be 1.

In the lower equation, on the other hand, Y can be any of 0 and 1 (as in the upper equation) when all are 0. Here, Y is limited to 0.

$$Y(c1, \text{file3}) <= 1/3(\text{access}(c1, \text{page1})^{*}x(\text{page1}, \text{file3}) + \text{access}(c1, \text{page2})^{*}x(\textit{page2}, \text{file3}) + \text{access}(c1, \text{page3})^{*}x(\text{page3}, \text{file3})) + 1 - 1/3 <= 1/3(0 + 0 + 0) + 2/3 <= 2/3$$

That is, Y is a 0-1 variable and therefore must be 0.

A third feature is to simplify the integer programming problem, which is a quadratic programming problem, into a linear integer programming problem. That is, when an integer programming problem is merely generated, the cost function takes a form of the sum of constant*X*Y where X indicates whether the page includes a file and Y indicates whether the file includes a component. Accordingly, the integer programming problem is a quadratic programming problem. This aspect is shown in FIG. **11**(*a*). In this case, the calculation time is increased.

For this reason, include from a file to a component is used as a constant and, instead, files representing all combinations are prepared, as shown in FIG. **11**(*b*). If the number of components is N, the number of files is 2^N-1. Thus, the problem can be represented by only X representing whether the page includes a file.

Specifically, files are connected as follows. Here it is assumed that the component is a Javascript function and the file is a Javascript file.

```
<html>
<head>
  <script src="test01.js" type="text/javascript"></script>
  <script src="test02.js" type="text/javascript"></script>
</head>
<body>
<script src="test03.js" type="text/javascript">
  function012(a, b, c);
 </script>
 </body>
 </html>
        test01.js is assumed to be:
function function011(a, b, c) {
  ....
}
function function012(a, b, c) {
  ....
}
        test02.js is assumed to be:
function function021(a, b, c) {
  ....
}
        test03.js is assumed to be:
function function031(a, b, c) {
 ....
}
```

First, test01.js, test02.js, and test03.js are merged to generate opt01.js below.

```
function function011(a, b, c) {
  ....
}
function function012(a, b, c) {
   ....
}
function function021(a, b, c) {
 ....
}
function function031(a, b, c) {
....
}
```

Then, using opt01.js, the HTML file is optimized as follows.

```
<html>
<head>
      <script src="opt01.js" type="text/javascript"></script>
      <script src="opt01.js" type="text/javascript"></script>
</head>
<body>
<script src="opt01.js" type="text/javascript">
      function012(a, b, c);
</script>
</body>
</html>
```

A fourth feature is to concatenate the same type of components using a combination of dependencies to reduce the number of components. That is, a reduction in the number of components can reduce the number of search files. What is

used at this time is a finding that components called from the same page are always finally incorporated into the same file regardless of how the optimization result is. Using this finding, components called from the same page as shown in FIG. **12**(*a*) are concatenated and redefined as a concatenated component as shown in FIG. **12**(*b*).

A fifth feature is to generate a candidate search file from a value representing whether a page transition, dependency, or speculative load is allowed.

To put it simply, 2^N-1 (N is the number of components) candidate files are generated. Accordingly, a reduction in the number of candidate search files reduces the calculation time.

Conceivably, combinations are classified as follows. That is:

(A) For X number of components used by a page i, 2^X-1 combinations are considered. All component combinations required by the page are prepared.

(B) Y number of components not used by the page i but used by another page included in the same page transition are added, and $2^{(X+Y)}-1$ combinations are considered. All component combinations required to perform a speculative download with respect to the page i are prepared. A speculative download with respect to the page i refers to that the page i previously loads components required by another page but not required by the page i and stores the components in the browser cache.

(C) A combination of components used only in any one of two page transitions cannot become an optimal solution. This is schematically shown in FIG. **13**. FIG. **14** is a diagram showing combinations of components when attention is paid to the page 1.

A sixth feature is to give priority to a particular transition pattern using a typical client and its importance. This feature is based on the need to selectively speed up a page or page transition having many users in proportion to the number of users or the need to selectively speed up a page or page transition important in terms of business.

A typical page transition and its importance are defined using the following method. First, web contents are placed, actual clients are allowed to use the web contents, and access logs are analyzed to obtain the number of users. The importance is determined according to the number of users obtained. Further, the developer or business owner defines a typical page transition. Furthermore, an addition where the cost of a page transition is weighted based on importance is added to the cost function. An example of such prioritization is shown in FIG. **15**. According to this drawing, the cost is calculated as follows: Cost=10* cost (page 1)+10* cost (page 2)+5* cost (page 2)+5* cost (page 3)+2* cost (page 3)

A seventh feature is to set the worst allowable response time for each page. It is useful to meet the need to avoid clients from waiting for particular seconds or more when they browse a page important in terms of business. A device for meeting such a need will be described. The device is represented by an equation as described below.

$$d + r \cdot \text{page_size}_1 + \sum_{m=1}^{M} \text{file_cost}_m \cdot x_{lm} \le T_l (l = 1, \ldots, L) \quad \text{[Formula 2]}$$

where L represents the number of pages and M represents the number of pages.

Use of this equation allows confining the time taken when the page is accessed without a browser cache, to a specified value T or less. This process is also done on a page for which the worst allowable response time is desired to be set.

As another device, the allowable response time can be set for all pages included in all page transitions. However, this device requires reformulation from the fundamental part, which can extend the run time. For this reason, this device is used according to the circumstances.

An eighth feature is to reduce the number of candidate files. Generally, the classification of a problem is changed according to the value an optimization variable x can take. That is, if x is a 0-1 variable, the problem is a 0-1 integer programming problem; if x is a real variable, the problem is a linear programming problem.

On the other hand, in an integer programming problem according to this embodiment, the number of variables (candidate files) is increased exponentially relative to the number of components, N. Accordingly, where N is large, a device for reducing the number of candidate files is needed. In this feature, if applicable, the integer programming problem is repeatedly solved as a linear programming problem using some candidate files. This leads to selection of a candidate file that is estimated to be most probably used as an optimal solution in a 0-1 integer programming problem.

First, the integer programming problem according to this embodiment is formulated as follows. That is, the following equation is solved as an objective function under the constraints below by a solver.

$$\sum_{k=1}^{K} \sum_{m=1}^{M} p_k \cdot y_{km} \cdot \text{file_cost}_m \quad \text{[Formula 3]}$$

where p_k represents the priority of a $page_k$.

$$\sum_{m=1}^{M} x_{lm} \cdot \text{include}(m, n) \ge 1 (\forall \text{ depend}(1, n) = 1) \quad \text{[Formula 4]}$$

$$y_{km} \ge \frac{1}{L} \sum_{l=1}^{L} \text{access}(k, 1) \cdot x_{lm} (k = 1, \ldots, K, m = 1, \ldots, M)$$

$$y_{km} \ge \frac{1}{L} \sum_{l=1}^{L} \text{access}(k, 1) \cdot x_{lm} + 1 - \frac{1}{L} (k = 1, \ldots, K, m = 1, \ldots, M)$$

$$x_{lm} \in (0, 1) (l = 1, \ldots, L, m = 1, \ldots, M)$$

$$y_{km} \in (0, 1) (k = 1, \ldots, K, m = 1, \ldots, M)$$

The algorithm will be described more specifically with reference to the flowchart of FIG. **16**. First, in step **1602**, the integer programming problem generation module **718** generates an integer programming problem using a few candidate files. The integer programming problem is passed to the solver **720**, which then in step **1604** relaxes the 0,1 constraint of the passed integer programming problem and solves the problem as a linear programming problem.

Here, a suffix set of intermediate variable constraints is defined as $N_l:=\{n|\text{depend}(1,n)=1\}$. Optimality is determined using information of a dual optimal solution. That is, the dual variable of the intermediate variable constraint is defined as β_{ln} (provided that only a pair of $n \epsilon N_l$ is prepared). Defining the dual optimal solution as β_{ln}, each $l \epsilon \{1, \ldots, L\}$ is checked

in $N'_l:=\{n|\beta^*_{ln}-q|\cdot r\cdot component_size(n)>0\}$ using the following formula.

$$\sum_{n\in N_{1r}} \{\beta^*_{ln} - q_1 \cdot r \cdot component_size(n)\} > q_1 d \quad \text{[Formula 5]}$$

Here, q_l is obtained as follows.

$$q_1 = \frac{1}{L} \cdot \sum_{Pattern_k\ including\ k\in page\ 1} p_k \quad \text{[Formula 6]}$$

A network delay time d has a value of approximately 10 to 50 ms in Japan. This is the time taken before a packet completes a round trip between a client and the server. A transfer efficiency value r is (the reciprocal of the bandwidth)×8. If the bandwidth is 1 Mbps, r=8/(1M).

"$Pattern_k$ including k ∈ page l" means that all ks where $access_{kl}$=1 are retrieved from page l and the ks are sequentially selected and subjected to Σ. p_k represents priority as shown in FIG. **15**.

If even one of l ∈ {1, . . . , L} is true in Formula 5 in step **1606**, the solution is determined not to be optimal. The integer programming problem generation module **718** then proceeds to step **1608** and adds N to the problem as a candidate file for improving the relaxation solution. The integer programming problem generation module **718** then returns to step **1604** to solve the linear programming problem again.

In contrast, if this equation is determined to be false with respect to all of l ∈ {1, . . . , L} in step **1606**, the solution is determined to be optimal and the process proceeds to step **1610**. The solver **720** solves an integer programming problem generated on the basis of an obtained candidate file and completes the process.

Next, the entire process according to this embodiment will be described with reference to the flowcharts of FIGS. **17** and later. In step **1702**, the measurement module **714** stores a network delay value in double d.

In step **1704**, the measurement module **714** stores a transfer efficiency value in double r.

In step **1706**, the measurement module **714** stores a page size in double[ ] page_size.

In step **1708**, the measurement module **714** stores a component size in double[ ] component_size.

In step **1710**, the dependency extraction module **704** extracts a dependency and stores it in int[][] depend.

In step **1712**, the dependency extraction module **704** stores a page transition in int[ ][ ] access.

In step **1714**, the dependency extraction module **704** stores the priority of a page transition in double[ ] priority.

In step **1716**, the dependency extraction module **704** stores, in double[ ] receptor, a determination as to whether a page accepts pre-reading of another page.

In step **1718**, the parameter setting module **710** stores the upper limit of the response time in double[ ] upper_time.

In step **1720**, the component concatenation module **706** concatenates the same type of components using a combination of dependencies to reduce the number of components.

In step **1722**, the candidate search file generation module **712** generates a candidate search file and stores it in int[ ][ ] include.

In step **1724**, the estimated load time calculation module **716** estimates the load time of the generated candidate file and stores it in double[ ] file_cost.

In step **1726**, the integer programming problem generation module **718** inputs the value of a variable into an optimization problem solver to obtain a solution x*.

In step **1728**, the reconfiguration module **722** reorganizes a library file from the output x*.

In step **1730**, the reconfiguration module **722** rewrites a link to the library file of each page into a link to the reorganized library file.

Next, referring to the flowchart of FIG. **18**, the process in which the measurement module **714** stores a network delay value in double d will be described. In step **1802**, the measurement module **714** obtains a network delay value (seconds) while accessing the communication interface **616** as necessary and stores the obtained value in a variable d.

Next, referring to the flowchart of FIG. **19**, the process in which the measurement module **714** stores a transfer efficiency value in double r will be described. In step **1902**, the measurement module **714** obtains a bandwidth value (bps) while accessing the communication interface **616** as necessary, divides 8 by the obtained value, and stores the division result in a variable r.

Next, referring to the flowchart of FIG. **20**, the process in which the measurement module **714** stores a page size in double[] page_size will be described. In step **2002**, the measurement module **714** keeps an array having a length of a page count L in an array page_size.

The process from step **2004** to step **2010** is repeated with respect to i=1 to L. In step **2006**, the measurement module **714** measures the size (byte) of page i. The size of page i is obtained, for example, by calling a predetermined API function of the operating system and obtaining the size of the HTML file of the page. In step **2008**, the measurement module **714** stores the size of page i in page_size[i]. As a result of this process, the size of each page is stored in page_size[ ] in bytes.

Next, referring to the flowchart of FIG. **21**, the process in which the measurement module **714** stores a component size in double[ ] component_size will be described. In step **2102**, the measurement module **714** keeps an array having a sufficient length in an array component_size. In step **2104**, index is set to 0.

The process from step **2106** to step **2120** is repeated with respect to all library files starting from a library file i=1.

In step **2108**, the measurement module **714** analyzes the library file i and divides it into components.

The process from step **2110** to step **2118** is repeated with respect to all components starting with a component j=1.

In step **2112**, the measurement module **714** measures the size (byte) of the component j. In step **2114**, the measurement module **714** stores the size of the component j in component_size[index]. In step **2116**, index is incremented by one. As a result of this process, the size of each component is stored in component_size[ ] in bytes.

Next, referring to the flowchart of FIG. **22**, the process in which the dependency extraction module **704** extracts a dependency and stores it in int[ ][ ] depend will be described. In step **2202**, the dependency extraction module **704** keeps an array having a page count L* and a component count N in a two-dimensional array depend.

Steps **2204** to **2218** form a loop with respect to page i=1 to L.

In step **2206**, the dependency extraction module **704** analyzes page i and identifies components the page i is using.

Steps **2208** to **2216** form a loop with respect to a component j=1 to N. In step **2210**, the dependency extraction module **704** determines whether the page i is using the component j. If Yes, it sets 1 in depend[i][j] in step **2212**; if No, it sets 0 in

depend[i][j] in step **2214**. When the loop from step **2208** to step **2216** completes with respect the components up to N, the dependence extraction module **704** proceeds to step **2218** and increments i by one, and returns to step **2204**.

When the loop from step **2204** to step **2218** completes with respect to L, the process completes. As a result of this process, the dependency between each page and each component is stored in depend[ ][ ].

Next, referring to the flowchart of FIG. **23**, the process in which the dependency extraction module **704** extracts a page transition and stores it in int[ ][ ] access will be described. In step **2302**, the dependency extraction module **704** keeps an array having a page transition count K* and a page count L in a two-dimensional array access.

Steps **2304** to **2216** form a loop with respect to a page transition i=1 to K.

Steps **2306** to **2314** form a loop with respect to a page j=1 to L. In step **2308**, the dependency extraction module **704** determines whether the page j is included in the page transition i. If Yes, it sets **1** in access[i][j] in step **2310**; if No, it sets 0 in access[i][j] in step **2312**. When the loop from steps **2304** to **2216** completes with respect to the page transitions up to K, the page transition information is stored in access[ ][ ].

Next, referring to the flowchart of FIG. **24**, the process in which the dependency extraction module **704** stores the priority of a page transition in double[ ] priority will be described. In step **2402**, the dependency extraction module **704** keeps an array having a length of a page transition count K in an array priority.

Steps **2404** to **2408** form a loop with respect to a page transition i=1 to K. In step **2406**, the dependency extraction module **704** inputs the priority of the page transition i in priority[i]. As a result of this process, the priority of each page transition is stored in priority[ ].

Next, referring to the flowchart of FIG. **25**, the process in which the dependency extraction module **704** stores a determination as to whether a page accepts pre-reading of another page in int[ ] receptor will be described. In step **2502**, the dependency extraction module **704** keeps an array having a length of a page count L in an array receptor.

Steps **2504** to **2512** form a loop with respect to a page i=1 to L. In step **2506**, the dependency extraction module **704** determines whether the page i accepts pre-reading. If Yes, it sets **1** in receptor[i] in step **2508**; if No, it sets 0 in receptor[i] in step **2510**. As a result of this process, information as to whether each page accepts pre-reading of another page is stored in receptor[ ].

Next, referring to the flowchart of FIG. **26**, the process in which the parameter setting module **710** stores the upper limit of the response time in double[ ] upper_time will be described. In step **2602**, the parameter setting module **710** keeps an array having a length of a page count L in an array upper_time.

Steps **2604** to **2608** form a loop with respect to a page i=1 to L. In step **2606**, the parameter setting module **710** inputs the limit of the response time of the page i in upper_time[i]. As a result of this process, the limit of the response time of each page is stored in upper_time[ ].

Next, referring to the flowcharts of FIGS. **27** and **28**, the process in which the component concatenation module **706** concatenates the same type of components using a combination of dependencies to reduce the number of components will be described. In step **2702**, the component concatenation module **706** keeps a flag array int[ ] flag having a length N.

In step **2704**, the component concatenation module **706** keeps a set-type variable array set[ ] S having a sufficient length and sets 1 for i in step **2706**.

In step **2708**, the component concatenation module **706** stores N pieces from c_i to c_N in S[**1**].

The process from step **2710** to step **2734** is repeated with respect to j=1 to L. The process from step **2712** to step **2720** is repeated with respect to k=1 to N. In step **2714**, the component concatenation module **706** determines whether page depend[j][k]==1. If Yes, it substitutes 1 into flag[k] in step **2716**; if No, it substitutes 1 into flag[k] in step **2718**.

After the loop from step **2712** to step **2720** completes with respect to N, the process from step **2722** to step **2734** is repeated with respect to k=1 to i. In step **2724**, the component concatenation module **706** determines whether flags corresponding to all components in S[k] are i. If Yes, it simply proceeds to the next loop of k. If No, it determines in step **2726** whether flags corresponding to all components in S[k] are 0. If Yes, it simply proceeds to the next loop of k. If No, it transfers all cs of flag==0 in S[k] to S[k+1] in step **2728**.

When the loop from step **2722** to step **2730** completes with respect to K, the component concatenation module **706** increments i by one in step **2732** and proceeds to the next loop of j in step **2734**. When the loop from step **2710** to step **2734** completes with respect to L, the process proceeds to the flowchart of FIG. **28**.

In step **2802**, the component concatenation module **706** overwrites the component size N with i calculated in step **2728**.

Steps **2804** to **2808** form a loop with respect to j=1 to N. In step **2806**, the component concatenation module **706** stores, in component_size[j], the sum of component sizes in s[j].

When the loop from step **2804** to step **2808** completes with respect to N, the component concatenation module **706** keeps an array having a page count L* and a component count N in a two-dimensional array depend in step **2810**.

Steps **2812** to **2824** form a loop with respect to i=1 to L, and steps **2814** to **2822** form a loop with respect to j=1 to N.

In step **2816**, the component concatenation module **706** determines whether the page i is using a component in S[j]. If Yes, it sets **1** in depend[i][j] in **2818**; if No, it sets 0 in depend[i][j] in **2820**. When the loop with respect to i=1 to L and an inner loop with respect to j=1 to N completes, this process completes. FIG. **29** is a diagram schematically showing an aspect of the processes of FIGS. **27** and **28**.

Next, referring to the flowcharts of FIGS. **30** and **31**, the process in which the candidate search file generation module **712** generates a candidate search file and stores it in int[ ][ ] include will be described.

In step **3002**, the candidate search file generation module **712** prepares a set-type variable Candidates. Steps **3004** to **3020** form a loop of with respect to k=1 to K.

In step **3006**, the candidate search file generation module **712** determines whether receptor of all pages included in a page transition k is 0. If Yes, it performs the process from step **3008** to step **3014**, which is a loop with respect to all pages_ included in the page transition k.

During the process from step **3008** to step **3014**, the candidate search file generation module **712** counts the number of components present in the page 1 and stores the counted number in Num in step **3010** and adds all of $2^{Num}-1$ combinations of components to Candidates in step **3012**. The candidate search file generation module **712** then proceeds to step **3020** and increments k by one.

If the candidate search file generation module **712** determines that receptor of all pages included in the page transition k is not 0, it counts the number of components on which pages included in the page transition k depend and adds the counted number to Num in step **3016**.

The candidate search file generation module **712** then adds all of $2^{Num}-1$ combinations of components to Candidates in step **3018** and proceeds to step **3020** and increments k by one.

When the loop from step **3004** to step **3020** completes with respect to the page transitions up to K, the process proceeds to the flowchart of FIG. **31**. The candidate search file generation module **712** sets 0 for i in step **3102** and then performs the loop from step **3104** to step **3108** with respect to all combinations of Candidates.

Since the loop includes step **3106** in which i is incremented by one, the completion of the loop from step **3104** to step **3108** means that the number of all combinations of Candidates is stored in i. In step **3110**, the candidate search file generation module **712** stores i in the number of candidate files, M.

In **3112**, the candidate search file generation module **712** keeps an array int[ ][ ] include having a length M×N and, in step **3114**, sets 1 for m.

The process from step **3116** to step **3130** is a loop with respect to all combinations of Candidates. The inner process from step **3118** to step **3126** is a loop with respect to n=1 to N.

In step **3120**, the candidate search file generation module **712** determines whether the combination includes a component n. If Yes, it sets **1** in include[m][n] in step **3122**; if No, it sets 0 in include[m][n] in step **3124**.

Next, when the loop from step **3118** to step **3126** completes with respect to the components up to N, the candidate search file generation module **712** increments m by one in step **3128** and proceeds to the next combination of Candidates in step **3130**.

When the loop from step **3116** to step **3130** completes, the candidate search file generation process completes.

Next, referring to the flowchart of FIG. **32**, the process in which the estimated load time calculation module **716** estimates the load time of the generated candidate file and stores it in double[ ] file_cost will be described.

In step **3202**, the estimated load time calculation module **716** keeps an array double [ ] file_cost having a length M.

The process from step **3204** to step **3216** is a loop with respect to m=1 to M. The estimated load time calculation module **716** sets 0 in file_size in step **3206**.

The process from step **3208** to step **3212** is a loop with respect to n=1 to N. In step **3210** within the loop, the estimated load time calculation module **716** calculates file_size+=include[m][n]* component_size[n].

After the loop from step **3208** to step **3212** completes with respect to N, the estimated load time calculation module **716** calculates file_cost[m]=d+r* file_size in step **3214**. The value d is obtained in the process of the flowchart of FIG. **18**, and the value r is obtained in the process of the flowchart of FIG. **19**.

Completion of the loop from step **3204** to step **3216** with respect to M means that file_cost[ ] is filled with the values.

FIG. **33** is a diagram schematically showing an aspect where the values calculated thus far are inputted into the solver **720** to obtain an optimal value. This corresponds to step **1726** of FIG. **17**. That is, d, r, receptor[ ], file_cost[ ], page_size[ ], component_size[ ], Upper_time[ ], include[][], access[][], priority[], x[][], and y[][]. depend[][] are inputted into the solver **720** to obtain X*[][], Y*[][].

At that time, the solver **720** solves the minimization of the value of Formula 7, which is already shown, under Formula 8 acting as constraint conditions.

$$\sum_{k=1}^{K}\sum_{m=1}^{M} p_k \cdot y_{km} \cdot \text{file_cost}_m \quad \text{[Formula 7]}$$

$$\sum_{m=1}^{M} x_{lm} \cdot \text{include}(m, n) \geq 1(\forall\ \text{depend}(1, n) = 1) \quad \text{[Formula 8]}$$

$$y_{km} \geq \frac{1}{L}\sum_{l=1}^{L} \text{access}(k, 1) \cdot x_{lm} (k = 1, \ldots, K, m = 1, \ldots, M)$$

$$y_{km} \geq \frac{1}{L}\sum_{l=1}^{L} \text{access}(k, 1) \cdot x_{lm} + 1 - \frac{1}{L} (k = 1, \ldots, K, m = 1, \ldots, M)$$

$$x_{lm} \in (0, 1) (l = 1, \ldots, L, m = 1, \ldots, M)$$

$$y_{km} \in (0, 1) (k = 1, \ldots, K, m = 1, \ldots, M)$$

Next, referring to the flowchart of FIG. **34**, the process in which the reconfiguration module **722** reorganizes a library file from an output x* will be described.

In step **3402**, the reconfiguration module **722** starts the loop from step **3402** to step **3420** with respect to l=1 to L.

Within the loop from step **3402** to step **3420**, the reconfiguration module **722** performs the loop from step **3404** to step **3418** with respect to m=1 to M.

In step **3406** within the loop from step **3404** to step **3418**, the reconfiguration module **722** determines whether x[l][m]==1. x[ ][ ] refers to what is denoted by X* in FIG. **33**.

If x[l][m]==1, the reconfiguration module **722** generates a file of a candidate file m in step **3406** and then performs the loop from step **3410** to step **3416** with respect to n=1 to N.

In step **3412** within the loop from step **3410** to step **3416**, the reconfiguration module **722** determines whether include [m][n]==1. If Yes, it adds a component n to the file and increments n by one in step **3416**; if No, it simply increments n by one in step **3416**.

When the loop from step **3410** to step **3416** completes with respect to the components up to N, the reconfiguration module **722** increments m by one in step **3418**.

Back in step **3406**, if not x[l][m]==1, the reconfiguration module **722** simply increments m by one in step **3418** and returns to step **3404**.

When the loop from step **3404** to step **3418** completes with respect to M, the reconfiguration module **722** increments l by one in step **3420** and returns to step **3402**.

When the loop from step **3402** to step **3420** completes with respect to L, the process completes. FIG. **35** schematically shows the above-mentioned process.

Next, referring to the flowchart of FIG. **36**, the process in which the reconfiguration module **722** rewrites a link to the library file of a page into a link to a newly generated library file will be described.

The reconfiguration module **722** performs the loop from step **3602** to step **3412** with respect to l=1 to L.

Within the loop from step **3602** to step **3612**, the reconfiguration module **722** performs the loop from step **3604** to step **3610** with respect to all links to library files in page[l].

In step **3606** within the loop from step **3604** to step **3612**, the reconfiguration module **722** searches for a smallest library file including a set of components of a linked library file.

In step **3608**, the reconfiguration module **722** rewrites a link into a link to the new library file.

When the process from step **3604** to step **3610** completes with respect to all links to library files in page[l], the reconfiguration module **722** proceeds to step **3612** and increments

l by one. The reconfiguration module **722** then returns to step **3602** and restarts the process from step **3604**.

When l reaches L in step **3602**, the process completes. FIG. **37** schematically shows the above-mentioned process.

While the present invention has been described on the basis of the specific embodiment, it should be understood that the invention can be realized by any computer hardware and platform. Further, a processing system according to the present invention can be used in the same way whether on a local client or on a server.

What we claim is:

1. A computer-implemented method for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser, the method comprising the steps of:

extracting dependencies between (i) pages, (ii) files, and (iii) components of the web page stored in a storage unit of the computer;

measuring (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size;

estimating load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size;

generating an integer programming problem using the information of the candidate file, wherein the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating a (i) dependency, (ii) an inclusion relationship and (iii) a loading relationship in the form of a 0-1 table;

solving the integer programming problem using a solver;

reconfiguring a library file from a solution to the integer programming problem obtained by the solver;

reconfiguring the web page by replacing a link to the library file of each page with a link to the reconfigured library file; and

wherein, at least one step is carried out using a computer device.

2. The method according to claim **1**, the method further comprising the step of:

concatenating same type of components using a combination of the extracted dependencies.

3. The method according to claim **1**, the method further comprising the step of:

connecting the files using information of the inclusion relationship, wherein at least one file includes components so as to form the integer programming problem into a linear integer programming problem.

4. The method according to claim **1**, the method further comprising the step of:

determining a set of successively accessed pages.

5. The method according to claim **4**, wherein a browser cache effect is added to a constraint condition of the integer programming problem, wherein the effect is such that a cost of an identical file is added only once.

6. The method according to claim **1**, the method further comprising the steps of:

solving a linear programming problem to find a relaxation solution to find a candidate file by using the solver; and

adding the found candidate file to solve the integer programming problem by using the solver.

7. A non-transitory computer readable storage device comprising a computer readable program which, when implemented, cause a computer to carry out the steps of a method for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser, wherein the method comprises the steps of:

extracting dependencies between (i) pages, (ii) files, and (iii) components of the web page;

measuring (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size;

estimating load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size;

generating an integer programming problem using the information of the candidate file, wherein the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating (i) a dependency, (ii) an inclusion relationship, and (iii) a loading relationship in the form of a 0-1 table;

solving the integer programming problem using a solver;

reconfiguring a library file from a solution to the integer programming problem obtained by the solver; and

reconfiguring the web page by replacing a link to the library file of each page with a link to the reconfigured library file.

8. The device according to claim **7**, wherein the device causes the computer to further perform the step of:

concatenating same type of components using a combination of the extracted dependencies.

9. The device according to claim **7**, wherein the device causes the computer to further perform the step of:

connecting the files using information of the inclusion relationship, wherein at least one file includes components so as to form the integer programming problem into a linear integer programming problem.

10. The device according to claim **7**, wherein the device causes the computer to further perform the step of:

determining a set of successively accessed pages.

11. The device according to claim **10**, wherein a browser cache effect is added to a constraint condition of the integer programming problem, wherein the effect is such that a cost of an identical file is added only once.

12. The device according to claim **7**, wherein the device causes the computer to further perform the steps of:

solving a linear programming problem to find a relaxation solution to find a candidate file by using the solver; and

adding the found candidate file to solve the integer programming problem by using the solver.

13. A system for reconfiguring a web page using a computer to reduce load time of the web page required when viewing the web page through a browser, the system comprising:

a non-transitory storage unit that stores (i) pages, (ii) files, and (iii) components of the web page;

a dependency extraction module that extracts dependencies between (i) pages, (ii) files, and (iii) components of the web page stored in the storage unit;

a measurement module that measures (i) a network delay value, (ii) a transfer efficiency value, and (iii) a component size;

an estimated load time calculation module that estimates load time of a candidate file using information of (i) the network delay value, (ii) the transfer efficiency value, (iii) the dependencies, and (iv) the component size;

an integer programming problem generation module that generates an integer programming problem using the

information of the candidate file, wherein the integer programming problem minimizes an object function representing the load time of the web page by analyzing the web page and generating a (i) dependency, (ii) an inclusion relationship, and (iii) a loading relationship in the form of a 0-1 table;

a solver that has the function of solving the integer programming problem;

a reconfiguration module that reorganizes a library file from a solution to the integer programming problem obtained by the solver; and

a reconfiguration module that reorganizes the web page by replacing a link to the library file of each page with a link to the reorganized library file.

14. The system according to claim **13**, further comprising:

a component concatenation module for concatenating the same type of components using a combination of the extracted dependencies.

15. The system according to claim **13**, further comprising:

an integer programming problem generation module that connects the files using information of the inclusion relationship where a file includes components so as to form the integer programming problem into a linear integer programming problem.

16. The system according to claim **13**, further comprising:

means that determines a set of successively accessed pages.

17. The system according to claim **16**, wherein a browser cache effect is added to a constraint condition of the integer programming problem, wherein the effect is such that a cost of an identical file is added only once.

18. The system according to claim **13**, wherein the solver has a function of solving a linear programming problem to find a relaxation solution to find a candidate file, and a function of adding the found candidate file to solve the integer programming problem.

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